ERDC/CERL TR-07-28

Construction Engineering Research Laboratory

US Army Corps of Engineers®
Engineer Research and Development Center

U.S. Army Corrosion Prevention and Control Program

Implementation of Electro-Osmotic Pulse Technology in Building P10000 at Fort Drum

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Construction Engineering Research Laboratory
U.S. Army Engineer Research and Development Center
2902 Newmark Drive
Champaign, IL 61822

Final report

Prepared for U.S. Army Installation Management Command (IMCOM)
Arlington, VA 22202

Under U.S. Army CPC Project IMA-1

Abstract: Hays Hall, headquarters for the U.S. Army 10th Mountain Division, has had a severe moisture intrusion problem since construction, with large volumes of water seeping through concrete walls and floors of the basement. The year after the building underwent acceptance commissioning, the basement flooded to a depth of 4 ft, and $200,000 worth of electronics and communications equipment was destroyed by water damage and severe corrosion. Sump pumps were installed to mitigate the water intrusion problem, but during the spring rainy season the pumps have been unable to completely eliminate water inflow. The basement still floods to a depth of several inches during heavy rains. One of the pumps had to be replaced after less than half its expected service life.

To address these continuing problems, an electro-osmotic pulse (EOP) system was installed in the basement of Hays Hall during the first and second quarters of Fiscal Year 2006. The system was activated in June 2006, and the U.S. Army Engineer Research and Development Center is monitoring long-term effectiveness of the system to prevent flooding of the basement. To date the EOP system is successfully preventing water intrusion and is keeping the interior walls and floors dry.

Contents

Figures and Tables

Figures

Tables

Introduction

This demonstration was performed for the U.S. Army Installation Management Command (IMCOM) under U.S. Army Corrosion Control and Prevention (CPC) Program Project IMA-1; Military Interdepartmental Purchase Requests MIPR5CCERB1011 and MIPR5CROBB1012, dated 15 December 2005. The proponent was the U.S. Army Office of the Assistant Chief of Staff for Installation Management (ACSIM). The technical monitors were Paul M. Volkman (IMPW-E) and David N. Purcell (DAIM-FDF).

The work was performed by the Materials and Structures Branch (CF-M) of the Facilities Division (CF), Construction Engineering Research Laboratory – Engineer Research and Development Center (ERDC-CERL). The Program Manager for the ERDC-CERL CPC Program was Dr. Ashok Kumar. The ERDC-CERL CPC Program Project Officer was Vincent F. Hock (CEERD-CF-M) and the Associate Project Officer was Orange S. Marshall, Jr. (CEERD-CF-M). The electro-osmotic pulse installation portion of this work was done by Drytronic, Inc., 17295 Chesterfield Airport Road, Chesterfield, MO 63005 under contract No. F09650-03-D001, Prime Order 5014. The President of Drytronic, Inc., is Paul D. Femmer. At the time this report was published, the Chief of the ERDC-CERL Materials and Structures Branch was Vicki L. Van Blaricum (CEERD-CF-M), the Chief of the Facilities Division was L. Michael Golish (CEERD-CF), and the Technical Director for Installations was Martin J. Savoie (CEERD-CV-ZT). The Deputy Director of ERDC-CERL was Dr. Kirankumar V. Topudurti and the Director was Dr. Ilker Adiguzel.

COL Gary E. Johnston was the Commander and Executive Director of ERDC, and Dr. James R. Houston was the Director.

Executive Summary

Hays Hall, headquarters for the U.S. Army 10th Mountain Division, has been affected by a severe moisture intrusion problem since it was constructed, with large volumes of water seeping through concrete walls and floors of the basement. The year after the building underwent acceptance commissioning, the basement flooded to a depth of 4 ft, and $200,000 worth of electronics and communications equipment was destroyed by water damage and severe corrosion. Sump pumps were installed to mitigate the water intrusion problem, but during the rainy season each spring the pumps have been unable to completely eliminate water inflow. The basement still floods to a depth of several inches during heavy rains. One of the pumps had to be replaced after less than half its expected service life.

To address these continuing problems, an electro-osmotic pulse (EOP) system was installed in the basement of Hays Hall during the first and second quarters of Fiscal Year 2006. The system was activated in June 2006, and the U.S. Army Engineer Research and Development Center is monitoring long term-effectiveness of the system to prevent flooding of the basement. To date the EOP system is successfully preventing water intrusion and is keeping the interior walls and floors dry.

Unit Conversion Factors

Multiply	By	To Obtain
degrees Fahrenheit	(5/9) x (°F – 32)	degrees Celsius
degrees Fahrenheit	(5/9) x (°F – 32) + 273.15.	kelvins
feet	0.3048	meters
inches	0.0254	meters
square feet	0.09290304	square meters
square inches	6.4516	square centimeters

1 Background

Overview

Hays Hall, building P10000 at Fort Drum, New York, serves as the Headquarters for the U.S. Army 10th Mountain Division. The structure was constructed in the late 1980s in a swampy area near the center of the cantonment area, possibly over an underground spring. The floor of the basement was constructed on two elevations. Approximately half of the floor is standard slab-on-grade construction and the other half is slab-on-grade below an elevated panel floor that is in the same plane as the non-elevated floor. Figure 1 shows the space between the concrete slab and the elevated panel floor installed in the basement.

Figure 1. Space below raised panel floor in Hays Hall basement.

The basement is the source of a severe moisture-intrusion problem at Hays Hall. Large amounts of water have continually seeped through concrete walls and floors of the basement since the building was constructed. The year after the building was put into service the basement flooded to a depth of 4 ft, destroying $200,000 worth of electronics and communications equipment through water damage and severe corrosion.

Sump pumps were installed to mitigate the water intrusion problem, but during spring rains the water inflow continues to exceed pumping capacity, and the basement still floods to a depth of several inches. One of the pumps failed in less than half its expected service life and had to be replaced at considerable cost.

To resolve this persistent water intrusion problem, an electro-osmotic pulse (EOP) moisture control system was installed in the basement of Hays Hall during the first half of Fiscal Year 2006 (FY06). The EOP system was activated in June 2006 and it is now successfully preventing water intrusion, keeping the interior walls and floors of the basement dry. The U.S. Army Engineer Research and Development Center – Construction Engineering Research Laboratory (ERDC-CERL) has begun long-term performance monitoring of the system to assess its ability to prevent water intrusion into the basement.

EOP technology offers an alternative water control method. It mitigates water seepage into the affected areas without requiring excavation, saving 40% or more compared with other approaches. EOP reduces corrosion of mechanical equipment and eliminates mold problems common in moist or excessively humid environments.

EOP technology

EOP technology is based on the principle of electro-osmosis, the movement of an electrically charged liquid under the influence of an external electric field. Electro-osmosis is not a new technology although new applications are being developed today. In 1809, F.F. Reuss originally described electro-osmosis in an experiment showing that water could be forced to flow through a clay/water system when an external electric field was applied to the soil (Reuss 1809).

EOP uses electro-osmosis for control of water intrusion within concrete structures. It uses pulsed, low-power direct current (DC) voltage fields to keep the interior surface of below-grade concrete or masonry structures dry and reduce indoor relative humidity. Past experience has shown that constant DC voltage used for moisture control deteriorated concrete over time. To prevent the chemical changes that cause the observed concrete deterioration, pulsed current was applied and shown to be effective. Figure 2 is a plot of the voltage versus time used in the Hays Hall EOP application. The plot depicts one complete pulse cycle.

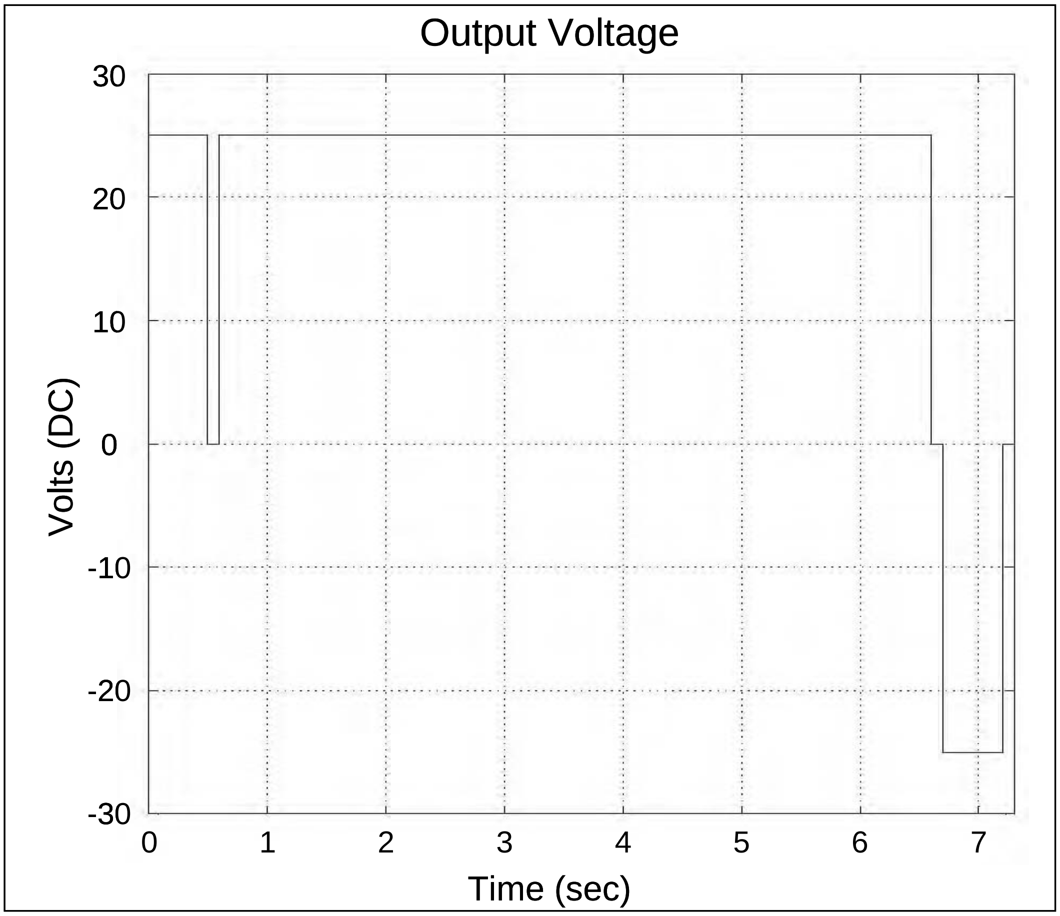


Figure 2. Plot of the voltage vs time used in Hays Hall.

The EOP system developed by ERDC-CERL and Drytronic, Inc., uses two sets of electrodes — one set of anodes and one set of cathodes. The anodes in the EOP system are embedded just below the surface of the concrete floors or walls. The cathodes are placed either in the surrounding soil or sometimes, if the wall is at least 2 feet thick, deep in the concrete floor or wall. Research has shown that when pulsing DC voltage is applied between the electrodes, it produces an electric field in the concrete floors and walls, which initiates hydraulic flow.

In basic terms, the EOP system uses pulses of electricity to reverse the flow of water seepage, causing moisture to flow out of the basement walls, and away from the building. The technology works by alternately pulsating a direct electric field with an off-period. The electric field consists of a pulse of positive voltage (as seen from the dry side of the concrete wall), followed by a pulse of negative voltage. Both pulses are followed by a brief nonenergized pause during which no voltage is applied. Of the three parts of the cycle, the positive voltage lasts the longest. The amplitude of the

positive signal is typically on the order of 20 – 40 volts DC (VDC). This positive electrical pulse causes cations (e.g., Ca++) and associated water molecules to move from the dry side (anode) toward the wet side (cathode) against the direction of flow induced by the hydraulic gradient, thus preventing water penetration through buried concrete structures. A critical aspect of this technology is the application of the negative voltage pulse, which depolarizes the electrodes, helping to maintain their efficiency, and controls the amount of moisture within the concrete, thereby preventing over-drying (and subsequent degrading) of the concrete matrix (McInerney et al., 2002). Figure 3 is diagram of the process.

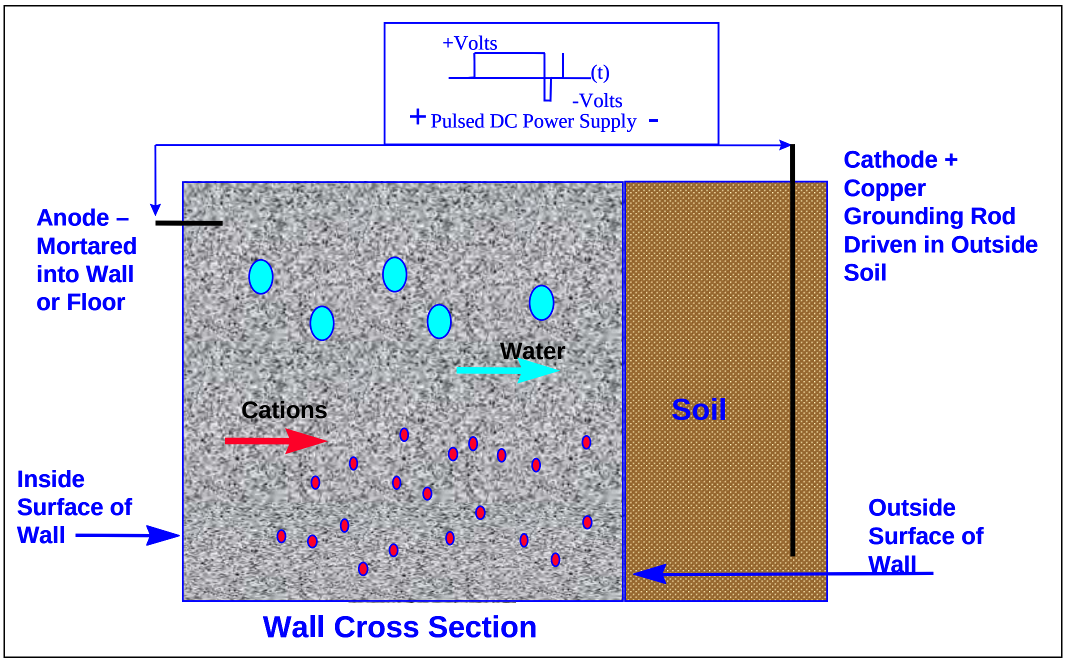


Figure 3. Illustration of EOP process.

For electro-osmosis to work effectively, specific conditions must be met. The first condition is that the medium to which electro-osmosis is applied to must contain capillary pores. Those same materials typically have the proper surface charges. In order for electrical current to flow through the medium, it must be wet with the pore fluid containing a dilute electrolyte. Finally, the electrical current must be applied in a way that minimizes chemical alteration of pore solution. Concrete, masonry, most stones used in construction, and clays meet all of these requirements.

Electro-osmosis has been used in civil engineering to (1) dewater dredgings and other water-saturated waste solids, (2) consolidate clays, (3) strengthen soft, sensitive clays, and (4) increase the capacity of pile foun-

dations. It has also received significant attention in recent years as a method to remove hazardous contaminants from groundwater or to arrest water flow.

Hays Hall EOP system installation

The EOP system in the basement of Hays Hall at Fort Drum, NY, was installed in three phases: (1) the non-secure area, (2) the Division Tactical Operations Center (DTOC) area, and (3) the Sensitive Compartmented Information Facility (SCIF) area. The installation of the electrodes and wiring was completed on May 12, 2006. Control panels for the system were installed on June 22, 2006, and the system was energized on June 23, 2006. Figure A1 in Appendix A shows the layout of the different construction phases.

Anodes

The anodes installed in the floors of the basement are Elgard™ 150 Ribbon Mesh (Figure 4). They consist of 0.75 inch wide titanium mesh with a precious metal oxide catalyst sintered coating. The product data sheet is included as Figures D1 and D2 in Appendix D. A total of 4,500 feet of ribbon mesh anode was installed (a) along the wall/floor junctures, (b) in-floor control joints, and (c) in construction joints in the floor. The anodes are divided into nine controlled zones with approximately 500 linear feet of anode per zone. The as-built drawing, Figure A2 in Appendix A, shows the locations of the anodes installed in the basement.

Cathodes

The cathodes are typical copper bonded ground rods, 0.5 inch in diameter. Figure D6 in Appendix D is the Product Data Sheet for the cathodes used. Thirteen cathodes were installed through the floor, and fourteen cathodes installed through the walls. The as-built drawing, Figure A2 in Appendix A, shows the locations of the cathodes installed in the basement of Hays Hall.

Figure 4. Photograph of anode ribbon installed in basement.

Stray current protection

Steel reinforcement is used in many concrete structures to increase the structural strength of the concrete, especially in tension, and to reduce cracking and spalling. When a DC electric field is initiated in the concrete, a portion of the current is conducted to the steel. This is the principle that makes cathodic protection of steel structures possible. The electrical current protects the steel from corrosion when the steel is the cathode. If, however, the steel is not the cathode, as is the case in EOP installations, corrosion will occur where the electrical current or stray current leaves the steel to flow toward the cathode. To prevent the stray current from leaving the reinforcing steel and corroding it, special circuitry was developed and included in the EOP system control unit that provides an alternate route to the cathode through the control unit. So the stray current goes back to the controller directly instead of jumping off of the reinforcement bar and going to the cathode, preventing that form of corrosion. The reinforcing steel in the basement of Hays Hall was bonded at 21 locations throughout the structure to provide protection from stray corrosion. The as-built drawing, Figure A2 in Appendix A, shows the locations of the stray current connections installed in the basement.

Floor cracks

All concrete cracks as it cures, as it is loaded, and as it ages. Some of the cracks are so small that they cannot be seen without magnification while other cracks can become so wide that they are easily seen from a distance. Steel reinforcement is typically used to reduce the cracking and limit crack width and growth. Often in floors and basements, cracks allow water to enter the strucure. Most water intrusion in basements or through floor slabs is the result of cracking. When an EOP system is installed, cracks that allow water intrusion are injected with a polyurethane grout and an anode is installed.

A substantial water leak was located under the elevated flooring in the Post & Division Plans Room. The leak was addressed by porting and injecting the cracked concrete with Strata-Tech 524 polyurethane grout. All other cracks that were found in the floor were routed with a ⅜ inch (9.5 mm) masonry cutter and filled with Micor two-part epoxy. Product data sheets for the grout (Figures D4 and D5) and epoxy (Figures D7 and D8) are included in Appendix D.

Control panels and wiring

Control panels for different zones of the EOP system are installed in three locations: (1) Electrical Room B28B, which contains cabinet EOP 1, (2) Janitor Room, which contains cabinet EOP 2, and (3) ASPS support in the SCIF, which contains cabinet EOP 3. EOP 1 controls five zones, EOP 2 controls two zones in the DTOC area, and EOP 3 controls two zones in the SCIF area.

All connections to the anodes are resistance-welded to half-inch wide titanium CD bars using 1/8 inch diameter titanium rods. The lead wires from the control unit are connected to the rods using electrical crimp connectors that are secured and made waterproof by encasing in thick polyolefin heat-shrink tubing. Figure 5 shows the anode connection. All wires are connected to the cathodes using exothermic welds applied using a Cadwell Plus One Shot (Figure 6). Appendix D contains data sheets for the heat-shrink tubing (Figure D11) and the weld material (Figure D9).

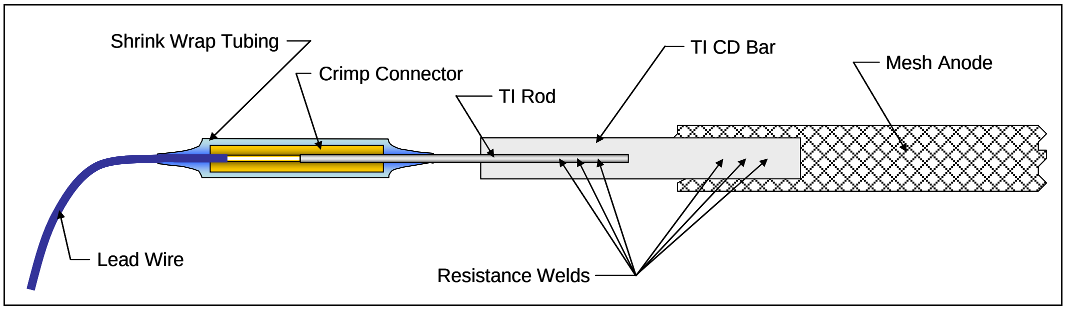


Figure 5. Drawing of the anode-lead wire connection.

All control wiring in the SCIF is embedded in a slot backfilled with Masterflow 928 grout. There are two surface-mounted junction boxes shown on the as-built drawing. The product data sheet for Masterflow 928 grout is included in Figure D3, Appendix D.

Figure 6. Cathode connection with exothermic weld.

All wiring used with the EOP system is multi-strand RHH AWG 14 wiring. The product data sheet for the wiring used is included in Figure D12, Appendix D. The wire code used for the installation is as follows:

- red wire – anode feeds
- blue wire – stray current/rebar connections
- green wire – cathode leads.

All EOP system junction boxes and conduit are clearly labled. A copy of the as-built drawing and the operator manual are maintained inside the

control unit panels. The as-built drawing in each panel clearly shows the area controlled by each zone within the panel.

Startup

The startup was performed without any complication. The control unit manufacturer, DSP Automation, assisted in the startup to ensure the proper controls were set to accommodate the rebar protection circuit. Zones 1 – 5 in cabinet EOP 1 have approximately equal resistance between the anode and cathode and between the anode and rebar, due to the rock encountered when installing the cathodes.

After the system was activated, it was monitored for 72 hours to ensure proper functioning of the electronic components. No failures were encountered. In cabinet EOP 2, Zone 4 was damaged due to operator error and was repaired. (The laptop computer being used to monitor the voltage and current settings was plugged into a grounded electrical circuit. Because both the control unit and the computer were grounded, the zone controller shorted out.) Table 1 presents the operating parameters at startup:

Table 1. Startup data (set at 5 amp limits).

Unit No.	Zone No.	Amps	Volts
EOP 1	01	5.5	13.6
	02	3.7	25.4
	03	1.6	27.1
	04	3.4	21.8
	05	3.3	19.6
	06	Spare	Spare
EOP 2	01	1.8	26.9
	02	1.6	27.1
	03	Spare	Spare
	04	Spare	Spare
EOP 3	01	2.1	25.7
	02	1.8	26.4

Other problems and resolutions

The exhaust and coolant lines for the generator in the basement generator room, B28A, were leaking at the wall penetrations (Figure 7). The contractor did not repair the leaks because they were to be addressed by the Fort Drum Directorate of Public Works (DPW).

The glycol line near the pumps for the building HVAC system leaked (Figure 8) and was repaired by contractors not involved in the EOP implementation.

During installation, it was further noted that water was leaking at two columns, one in Electrical Room 1 and the other in Mechanical Room 2 (Figure 9). The water was entering from the upper stories. It was unclear if the source of the water was condensation on the steel columns, a faulty roof connection, or water entering through a crack in the masonry wall. Resoultion of this problem was assigned to the Fort Drum DPW.

Figure 7. Exhaust and coolant lines through wall in Room B28A.

Figure 8. Glychol on floor of Mechanical Room 2.

Figure 9. Water on steel column in Mechanical Room 2.

2 Lessons Learned

Installing the EOP system in the SCIF presented several challenges. One issue was that installation of the EOP cathodes required new wall and floor penetrations. Many electrical devices that extend outside the perimeter of the SCIF can potentially transmit information or be used as a source for information gathering by hostile agents. A special waiver was granted by the Defense Intelligence Agency (DIA) to install the cathodes. In order to obtain the waiver it was necessary for ERDC-CERL show that the cathodes would not send a signal into the surrounding soil and that the electrical current produced by the EOP system could not be used as a source for hostile operatives to gather information from inside the SCIF. Previous documentation submitted for EOP work performed in Korea was used to acquire the waiver needed.

Another restriction on installing the EOP system in the SCIF dealt with communications between the EOP control units. In order to coordinate electrical pulses throughout the EOP system it is necessary for the control units to communicate with each other, typically using a standard copper communications cable. Because an unprotected copper communications cable is not allowed to extend outside the SCIF, a one-way fiber optic capability was devised to enable the controllers to communicate without creating a security vulnerability. Analysis of the installed EOP system indicated that the EOP system inside the SCIF is completely independent of that installed in the rest of the basement. Consequently, it was determined that the controller communication into the SCIF would not be necessary.

One other challenge related to performance monitoring of the EOP system. As a part of the monitoring, relative humidity/temperature (RH/T) sensors with data loggers were placed at selected locations in the basement. In addition, the control units have built-in data loggers to record voltages and error logs in case there is a problem with the EOP system operation. Permission was obtained to place an RH/T sensor under the raised floor of the SCIF. However, special permission must be obtained from DIA to retrieve the data from the RH/T sensor and from the control unit data loggers.

3 Technical Investigation

Problem

Water intrusion into the basement of Hays Hall has not only destroyed expensive electronic equipment, as noted previously, but also has caused corrosion degradation of steel-reinforced concrete and structural steel members. Four sump pumps were installed to prevent future flooding, but the spring rains can still cause basement flooding to a depth up to 2 inches above the raised floor. One of the pumps failed years before reaching its service life, and the others are also expected to fail prematurely.

Moisture intrusion not only causes severe corrosion but also promotes mold and bacteria growth, contributing to poor air quality and aggravating allergies and respiratory problems in soldiers who work in confined spaces of the basement. Half of the affected basement area is mission-critical because it houses the Division command and control center. The water intrusion problem can make the structure unsafe to occupy, particularly during the spring thaw. Figure 10 shows corrosion of supports for the elevated floor in the Division Tactical Operations Center. Figure 11 shows mold growing in the same area.

Conventional concrete and masonry waterproofing treatments such as trenching around a structure and installing a waterproofing membrane or installing a membrane and drain are temporary measures, lasting only a few years before repeated treatment or extensive maintenance is required. Such measures are labor-intensive, time consuming, disruptive, and likely to fail before long. In addition, such treatments do not address water intrusion through the floor. A more effective permanent solution to the Hays Hall water intrusion problem was needed.

Figure 10. Corrosion of elevated floor supports and frame.

Figure 11. Mold growth on walls under elevated floor.

Objective

The objective of this work was to design an EOP system for the basement of Hays Hall, install it, and monitor its performance in preventing water intrusion into the basement.

Approach

The EOP design for the building was based on draft design guidance developed by ERDC-CERL engineers. The design and implementation will be validated through periodic monitoring of the effectiveness of EOP in preventing water intrusion into the basement.

Results

There has been no water intrusion observed in the basement of Hays Hall since the EOP system was installed and activated. Appendix B shows plots of the protimeter data obtained. Figure B1 shows the locations from which the data were obtained. Overall, there was a rise in concrete surface moisture during the 52 day period before activating the system. After activation there was a decrease in surface moisture, with a few exceptions. More data collection will better define the concrete moisture trends.

The goal of measuring of the voltage and current output for each zone at the control units was to collect ongoing data that would indicate whether the concrete was drying out. If the voltage and current are known, the resistance in the concrete can be calculated using Ohm's Law:

$$V = RI \tag{1}$$

where V is the voltage applied to the zone, R is the sum of the resistances of the conductor wires, the anodes, and the concrete, and I is the current. Because the applied voltage and conductor lengths are constant, a change in current directly indicates a change of resistance in the concrete. Wet concrete readily conducts electric current. As the concrete dries out, the resistance will increase and the current draw will decrease.

When the data collected by the data loggers for the zone control units were downloaded and analyzed, it was discovered that the data were not reliable. Those data were not recorded in correct sequence and much of the information was missing. Also, the readings were not recorded at the same point in the pulse cycles over time. The control unit manufacturer is currently reprogramming the control unit to correct the problems.

The temperature and relative humidity sensor data were collected and compared with the temperature, relative humidity, and rainfall data pro-

vided by Fort Drum. Figure C1 shows where the sensors are located. Figures C2 – C8 show the sensor data.

4 Metrics

EOP performance validation is based on monitoring the system's effectiveness as designed to prevent moisture intrusion in the basement. The monitoring program addresses the following parameters:

- *Periodic measurement of the surface moisture of the concrete at selected locations in the basement.* Figure B1 in Appendix B shows the basement locations where the surface moisture measurements are taken. The relative surface moisture is measured using a protimeter, which measures electrical resistance between two probes in contact with the concrete and converts the resistance to a moisture percentage level. Measurements were taken before the EOP system was activated, 2 days after activation, and then every 42 days afterward. (Forty-two days was the period selected because that is the memory capacity of the control unit data loggers.)
- *Measurement of the voltage and current output for each zone at the control units.*
- *Monitoring of relative humidity and temperature at selected locations in the basement of Hays Hall.* Figure C1 shows the locations of the sensors. The temperature and humidity data are measured and recorded on an internal data logger every 3 hours. From the data, dew point is calculated. Local weather data are also being obtained from the Army airfield on Fort Drum for comparison with the sensor data.

5 Economic Summary

Projected ROI

Total funding for this work was $455,000. Of that total, $355,000 was applied to the installation contract and $100,000 was used for contract development and oversight and performance monitoring. The projected return on investment (ROI) is 9.35. The assumptions and calculations are summarized below.

Assumptions

Fort Drum paid $250,000 to install four sump pumps soon after building construction. The estimated life of the pumps is about 10 years. However, the DPW had to replace one pump at 6 years. Fort Drum pays $8,000 – $10,000 per year for energy to run the pumps and the DPW must maintain the pumps at an estimated cost of $4,000 per year. Before installing the pumps, water levels in the basement were reaching depths of up to 4 feet, and the installation had to replace computer and communications equipment for the 10th Mountain Division valued at around $200,000, according to the Chief of the Fort Drum Engineering Division. Even with the sump pumps operating, water still floods portions of the basement occasionally, particularly during spring. The cleanup and drying of equipment as a result of water intrusion is estimated at $5,000 per year. A sickness cost avoidance of $2,000 per month due to lost productivity and medical surveillance and treatment is assumed. Associated with sickness avoidance is a similar amount of cost avoidance for litigation and investigations.

Because one sump pump failed 2 years ago, it is assumed that the remaining three pumps will need to be replaced within 1 or 2 years. The pump replacement cost is estimated to be $65,000 per unit. The expected service life of each pump is about 8 years. It is assumed that existing floor coverings require replacement every 5 years due to water damage at a cost of $48,000 ($4.00/sq ft); and furniture and vending machines at a cost of $8,000. It is also assumed that the raised floor will need to be replaced every 15 years due to corrosion of the supports, at a cost of $320,000.

The EOP system will avoid the costs cited above by eliminating water intrusion through the walls and floors of the basement area, which will effec-

tively eliminate the main sources of water. The following table summarized the ROI calculation.

Table 2. ROI calculations for Hays Hall EOP system.

Return on Investment Calculation

Investment Required			455,000
Return on Investment Ratio	9.35	Percent	935%
Net Present Value of Costs and Benefits/Savings	3,226	4,255,410	4,252,184

A Future Year	B Baseline Costs	C Baseline Benefits/Savings	D New System Costs	E New System Benefits/Savings	F Present Value of Costs	G Present Value of Savings	H Total Present Value
1	78,000		260	253,000	243	309,353	309,110
2	134,000		260	253,000	227	338,006	337,779
3	396,000		260	253,000	212	529,779	529,566
4	13,000		260	253,000	198	202,931	202,733
5	13,000		260	253,000	185	189,658	189,473
6	78,000		260	253,000	173	220,545	220,372
7	69,000		260	253,000	162	200,509	200,347
8	13,000		260	253,000	151	154,812	154,661
9	78,000		260	253,000	141	180,031	179,889
10	78,000		260	253,000	132	168,247	168,115
11	78,000		260	253,000	124	157,258	157,135
12	69,000		260	253,000	115	142,968	142,853
13	13,000		260	253,000	108	110,390	110,282
14	78,000		260	253,000	101	128,362	128,261
15	13,000		260	253,000	94	96,398	96,304
16	13,000		260	253,000	88	90,094	90,006
17	134,000		260	253,000	82	122,524	122,442
18	396,000		260	253,000	77	192,039	191,962
19	78,000		260	253,000	72	91,522	91,450
20	13,000		260	253,000	67	68,734	68,667
21	13,000		260	253,000	63	64,239	64,176
22	134,000		260	253,000	59	87,346	87,287
23	13,000		260	253,000	55	56,099	56,045
24	13,000		260	253,000	51	52,429	52,377
25	78,000		260	253,000	48	60,970	60,922
26	78,000		260	253,000	45	56,998	56,953
27	134,000		260	253,000	42	62,268	62,226
28	13,000		260	253,000	39	40,006	39,967
29	13,000		260	253,000	37	37,400	37,363
30	78,000		260	253,000	34	43,493	43,459

6 Recommendation

It is recommended that the use of EOP technology be promoted as a solution to water intrusion in on-grade and below grade concrete military buildings.

7 Implementation

A contract was awarded in Fiscal Year 2006 to update existing U.S. Army Corps of Engineers criteria and guidance documents to include, where appropriate, specifications and instruction on implementing EOP technology for prevention of the intrusion of water, and related corrosion, in buildings. Affected documents will include current Unified Facilities Guide Specifications (UFGS), Engineer Manuals, and Technical Manuals. Also included in this effort will be a rewrite of a draft Engineer Instruction for EOP and a new UFGS dedicated to EOP technology.

8 Conclusion

After an electro-osmotic pulse system was installed and activated in the basement of Hays Hall at Fort Drum, NY, the observable water intrusion sources were eliminated.

The EOP system is performing as designed to stop and prevent water intrusion through the basement floors and walls.

In addition to keeping water from entering the basement, the system is actively reducing the concrete moisture and the relative humidity within the basement.

Appendix A: Hays Hall As-Built Drawings

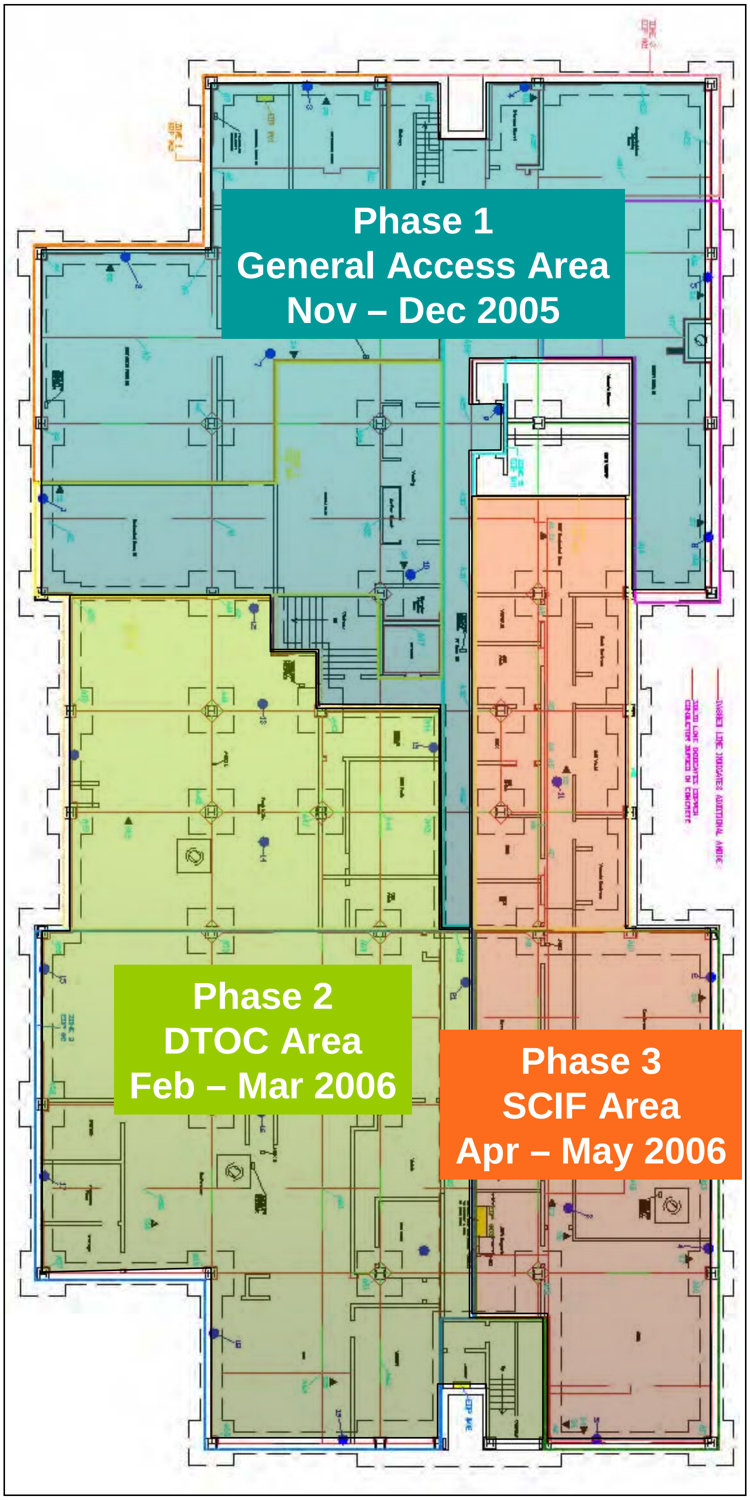


Figure A1. EOP construction phases.

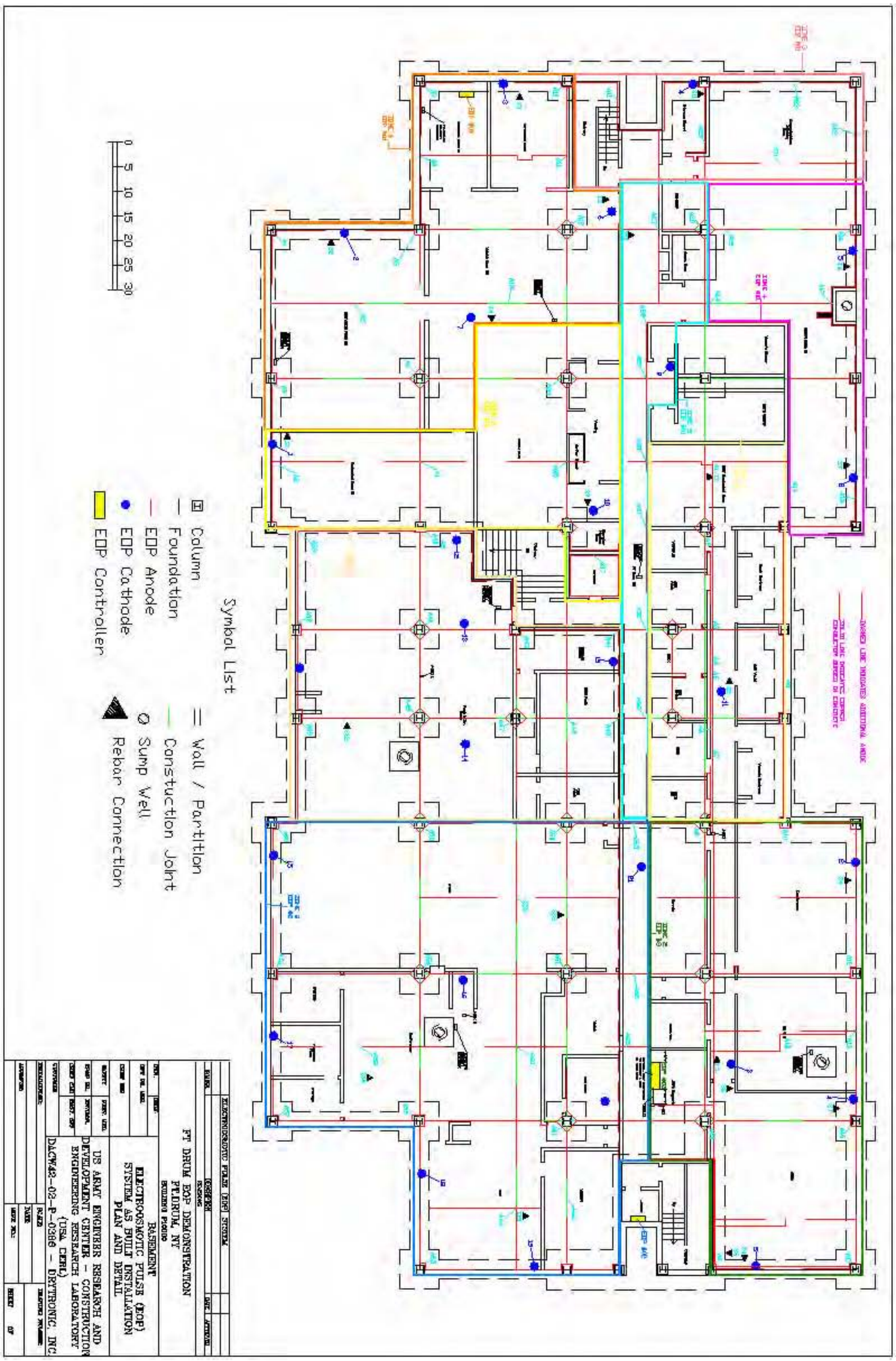


Figure A2. As-built drawing of EOP system installed in Hays Hall.

Appendix B: EOP System Performance as Indicated by Concrete Surface Moisture

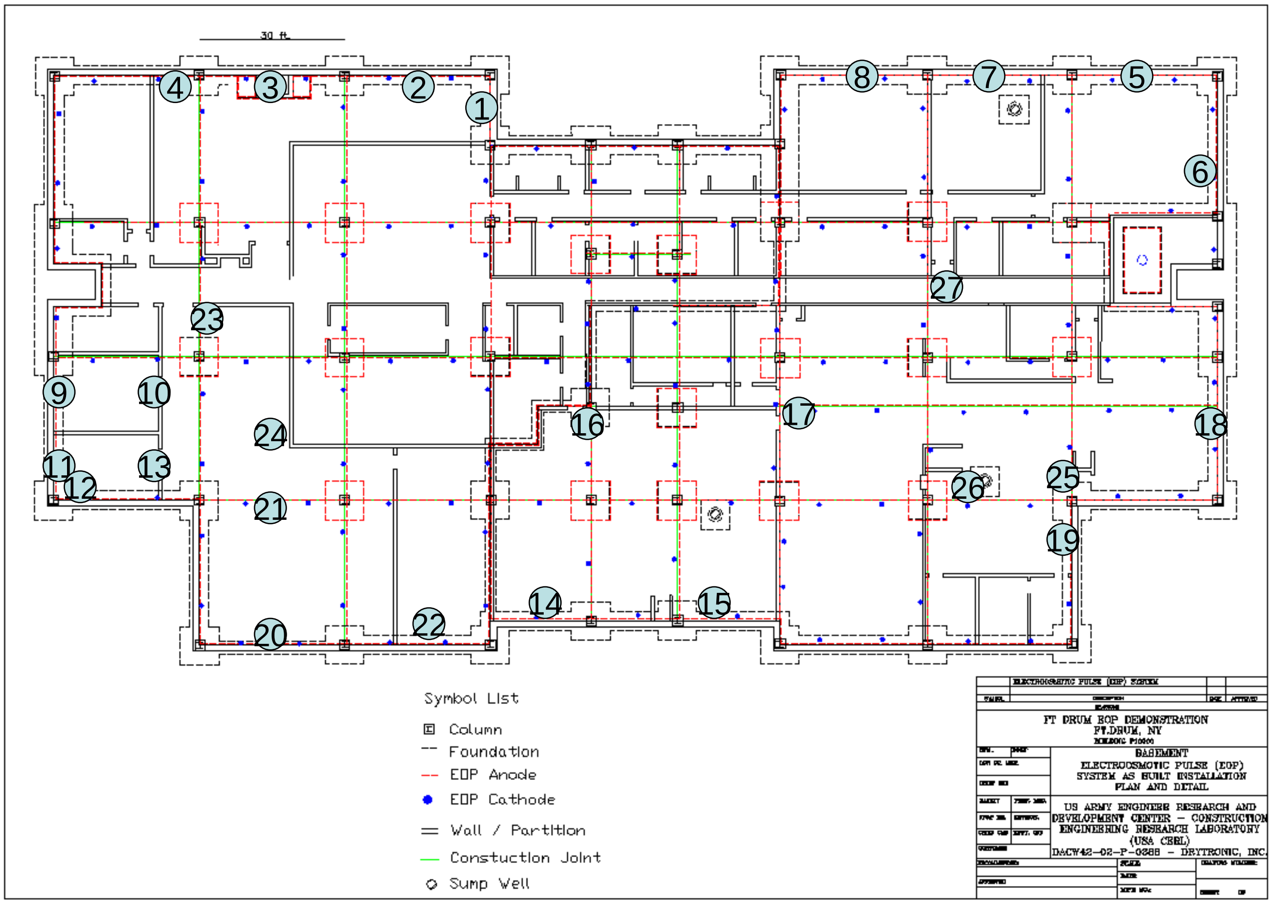


Figure B1. Surface moisture sampling locations.

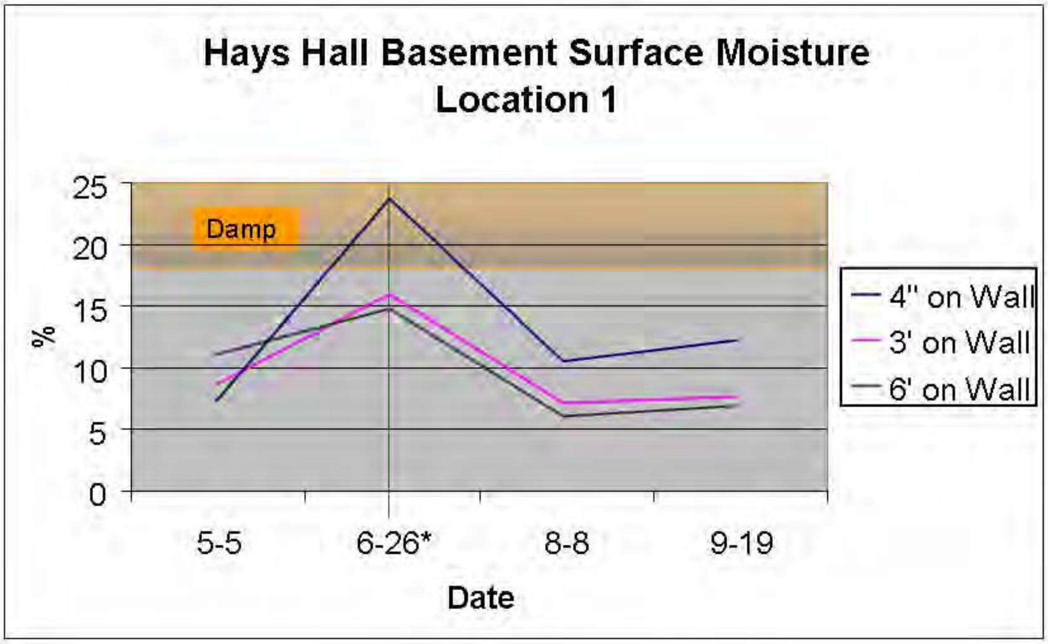


Figure B2. Plot of surface moisture vs time for Location 1.

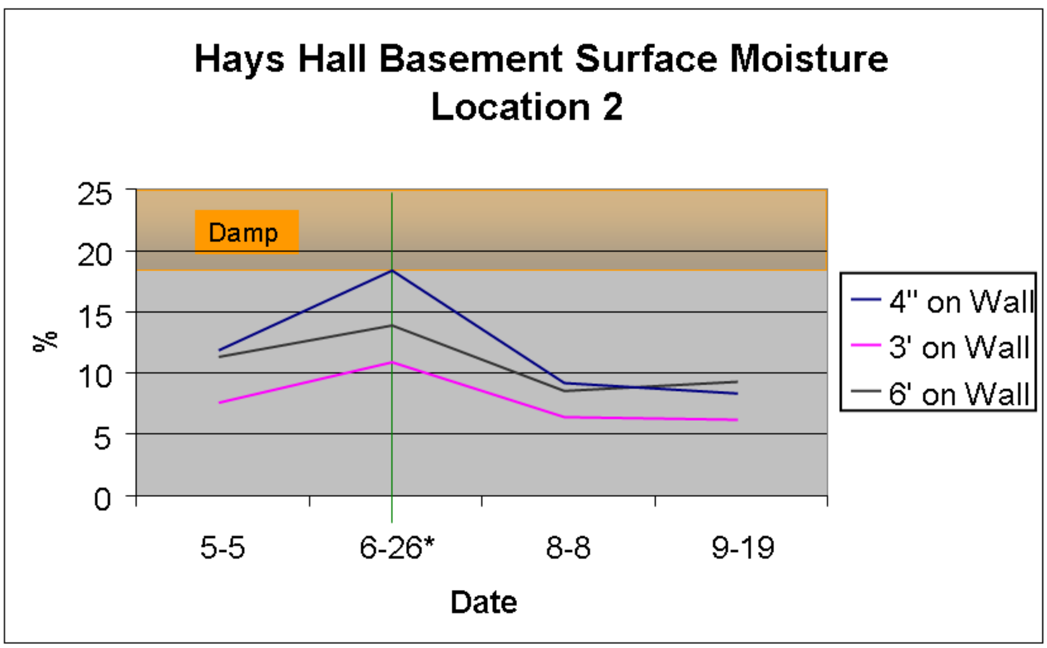


Figure B3. Plot of surface moisture vs time for Location 2.

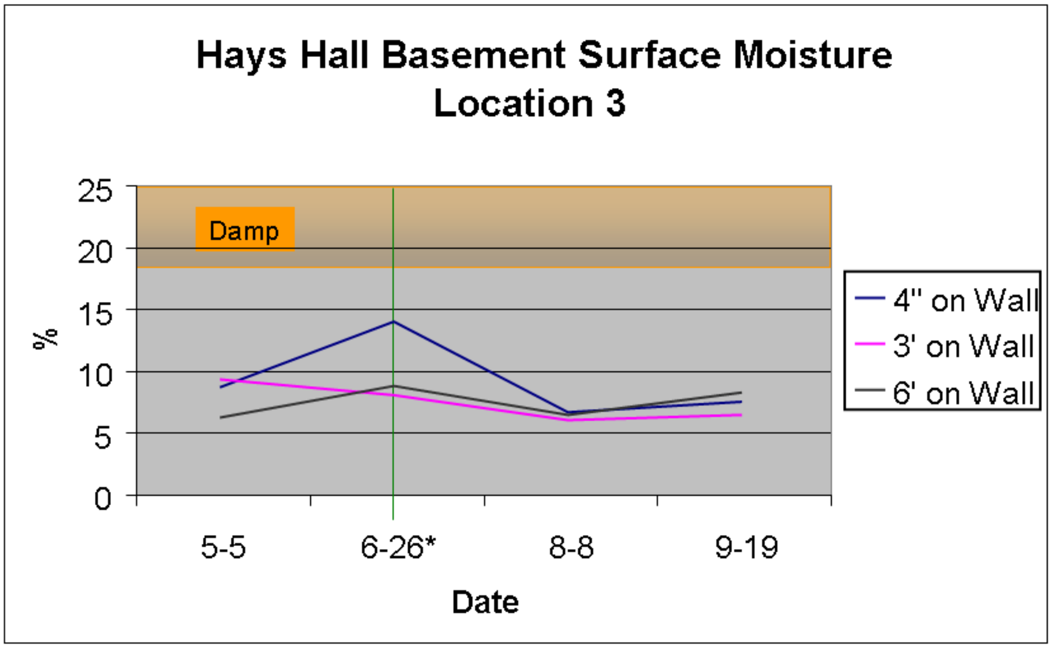


Figure B4. Plot of surface moisture vs time for Location 3.

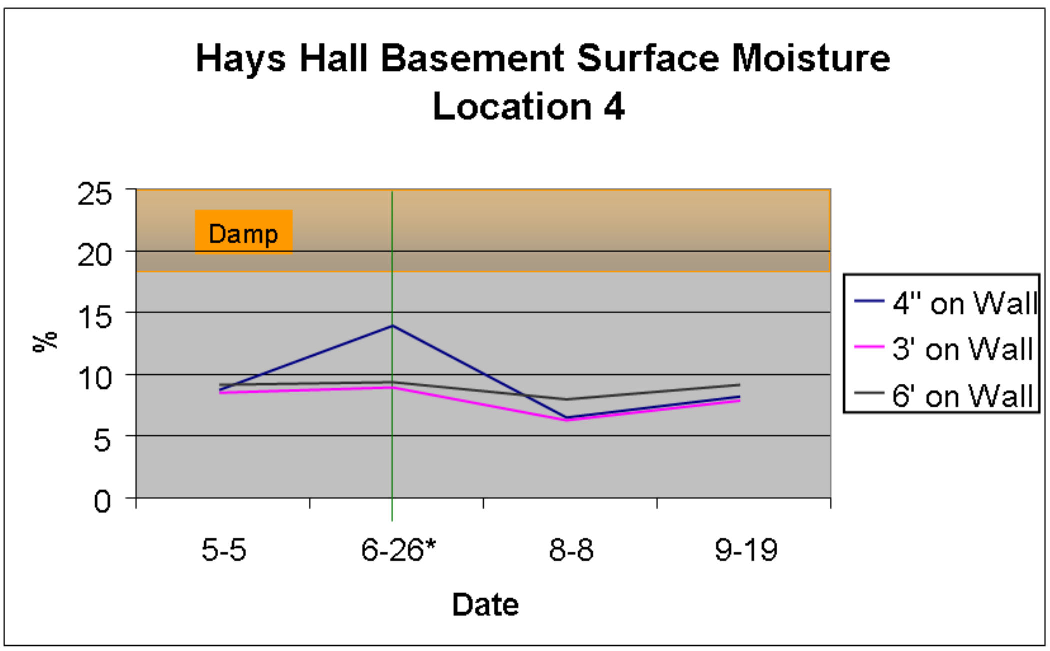


Figure B5. Plot of surface moisture vs time for Location 4.

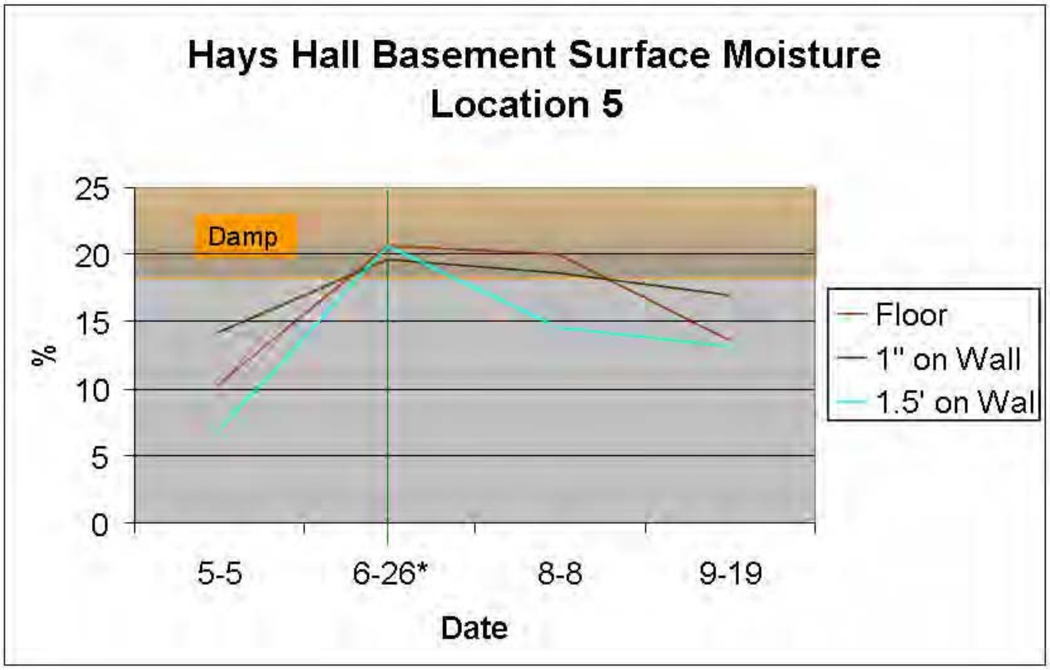


Figure B6. Plot of surface moisture vs time for Location 5.

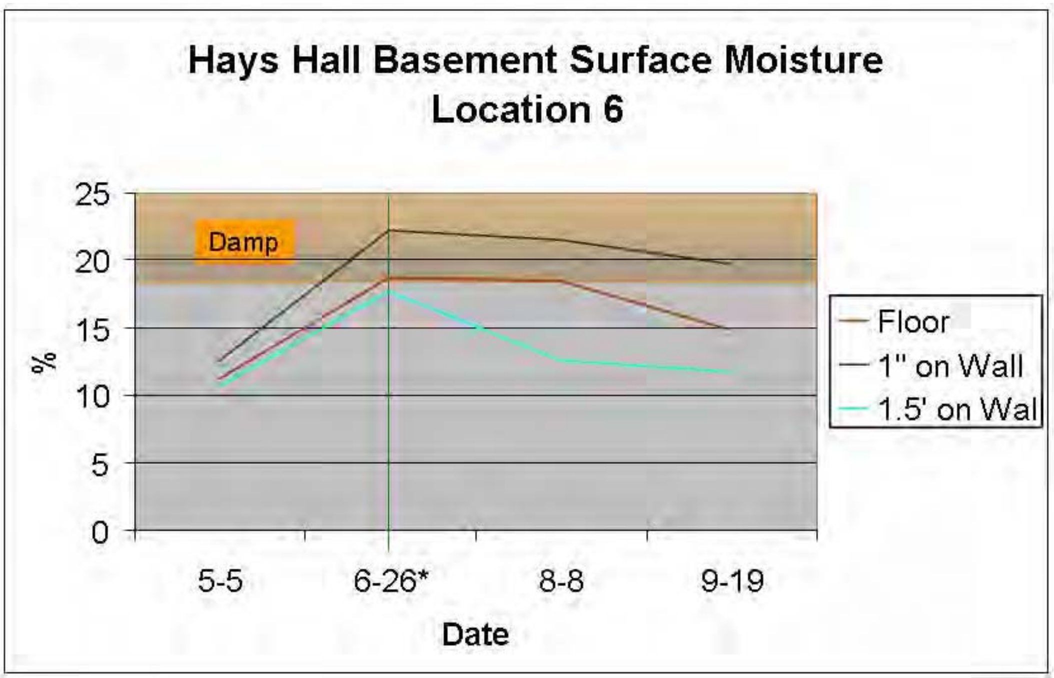


Figure B7. Plot of surface moisture vs time for Location 6.

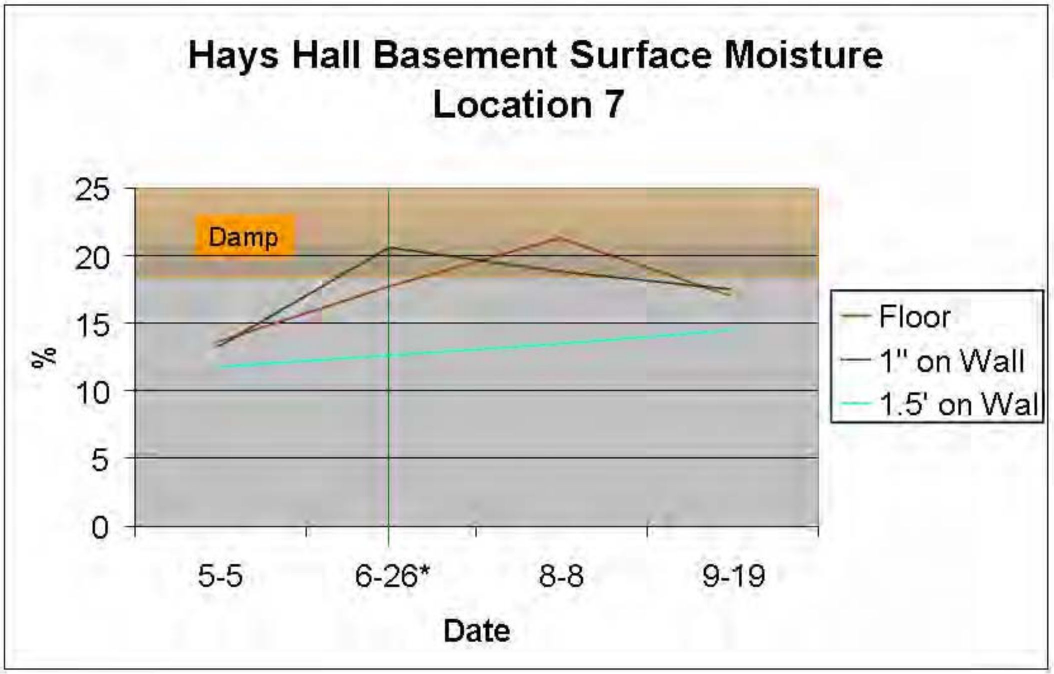


Figure B8. Plot of surface moisture vs time for Location 7.

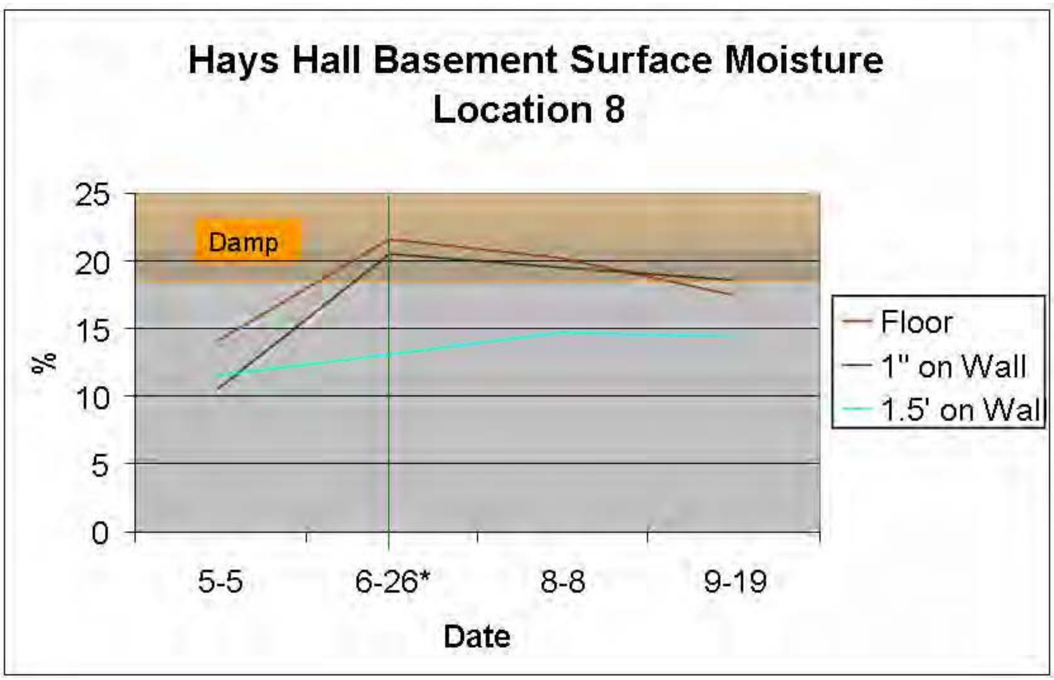


Figure B9. Plot of surface moisture vs time for Location 8.

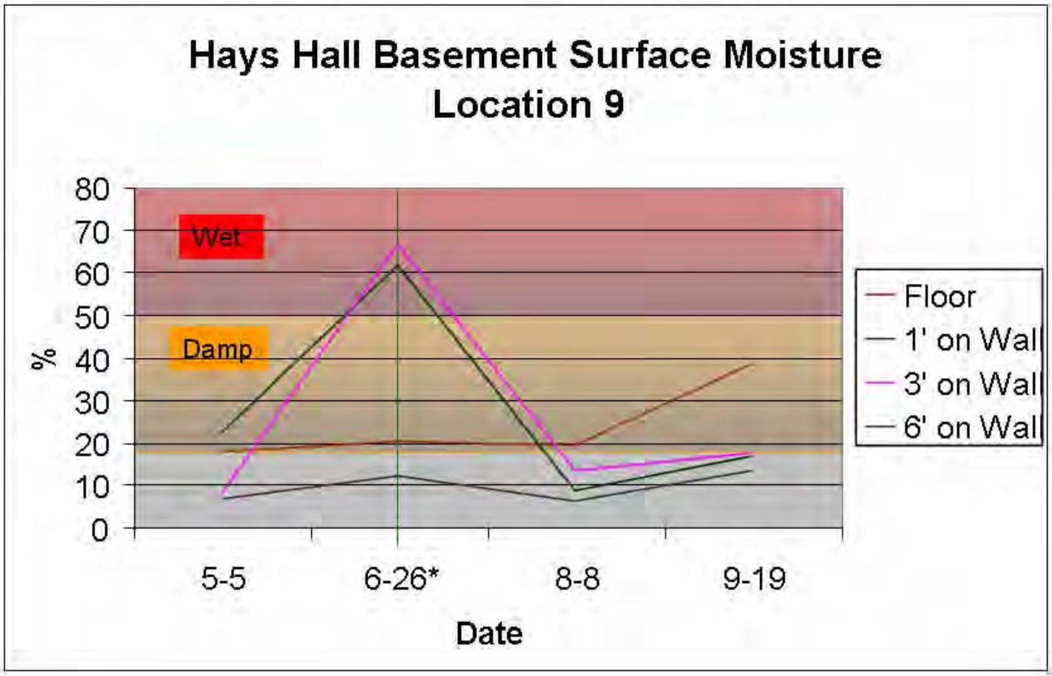


Figure B10. Plot of surface moisture vs time for Location 9.

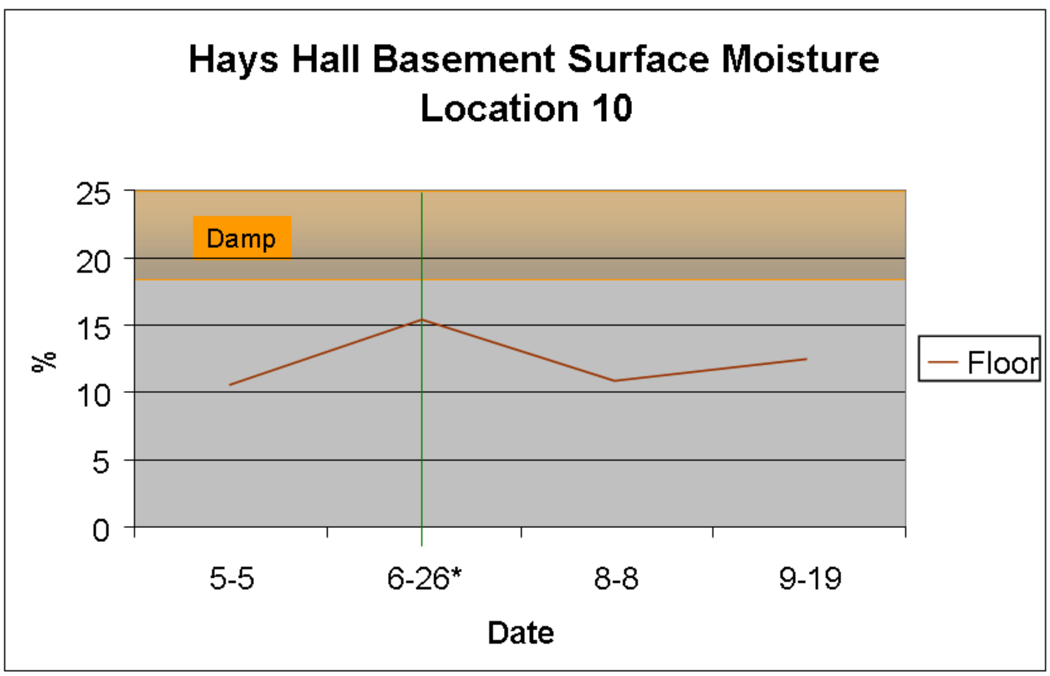


Figure B11. Plot of surface moisture vs time for Location 10.

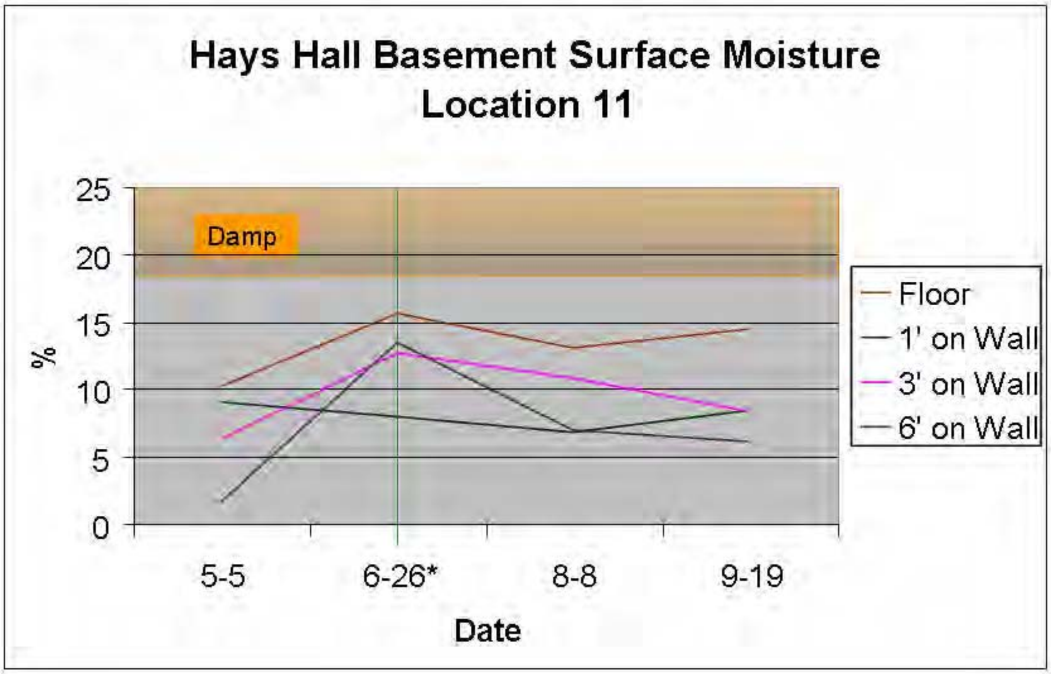


Figure B12. Plot of surface moisture vs time for Location 11.

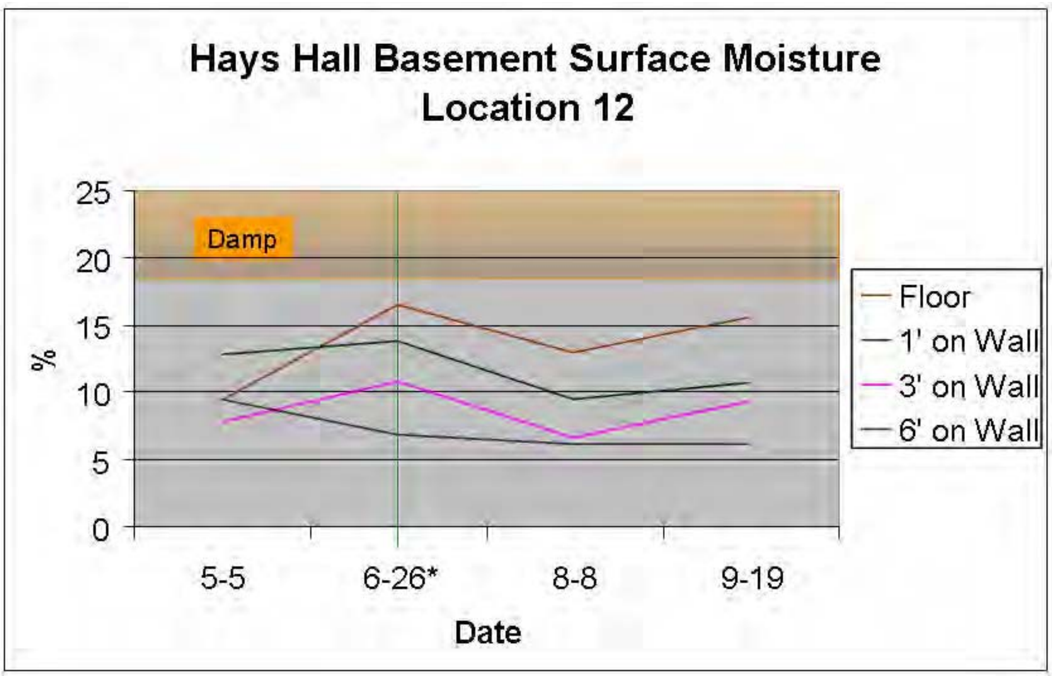


Figure B13. Plot of surface moisture vs time for Location 12.

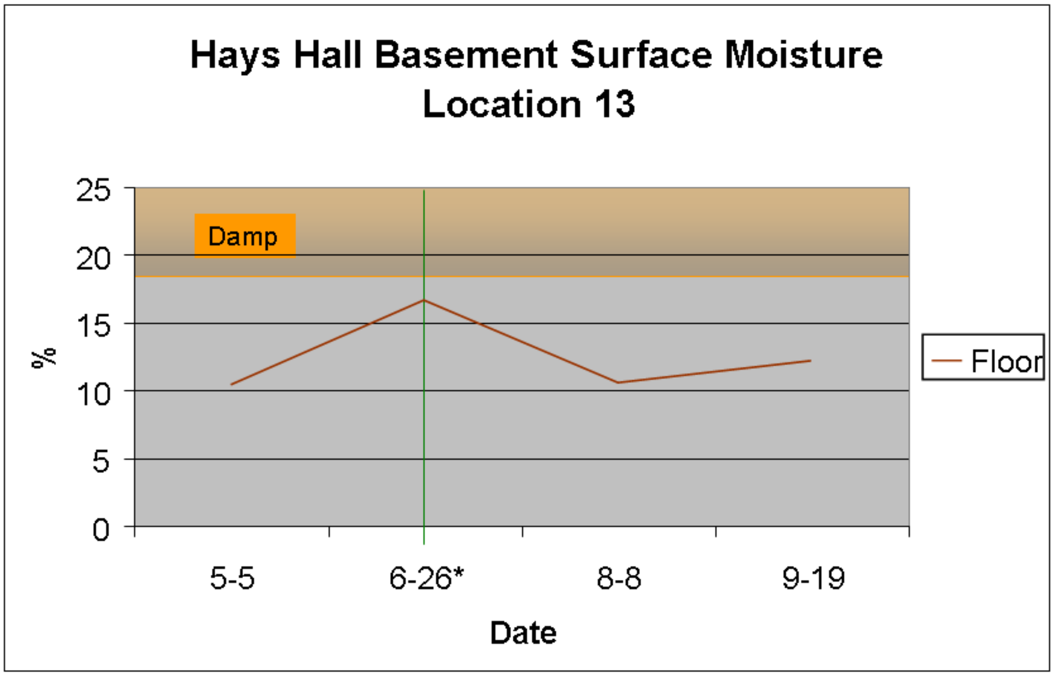


Figure B14. Plot of Surface moisture vs time for Location 13.

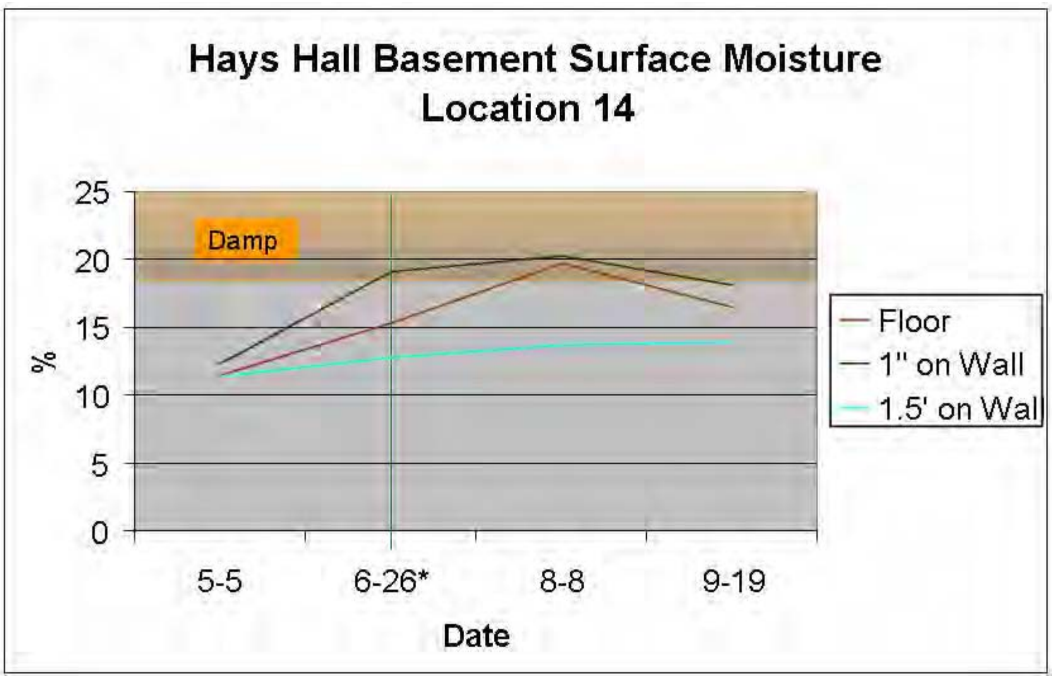


Figure B15. Plot of surface moisture vs time for Location 14.

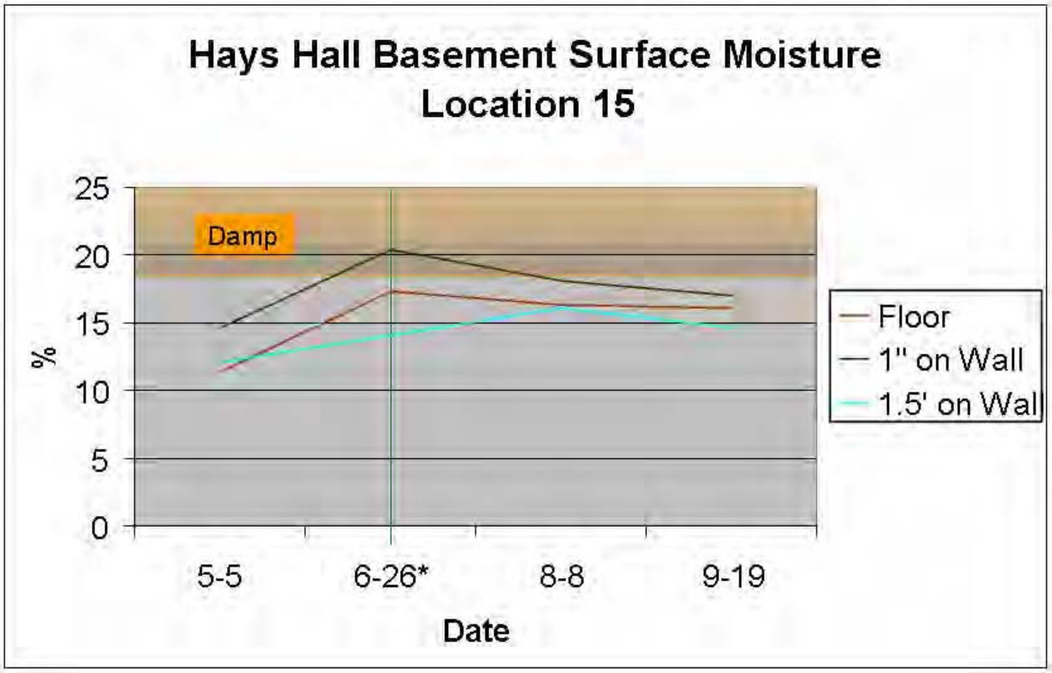


Figure B16. Plot of surface moisture vs time for Location 15.

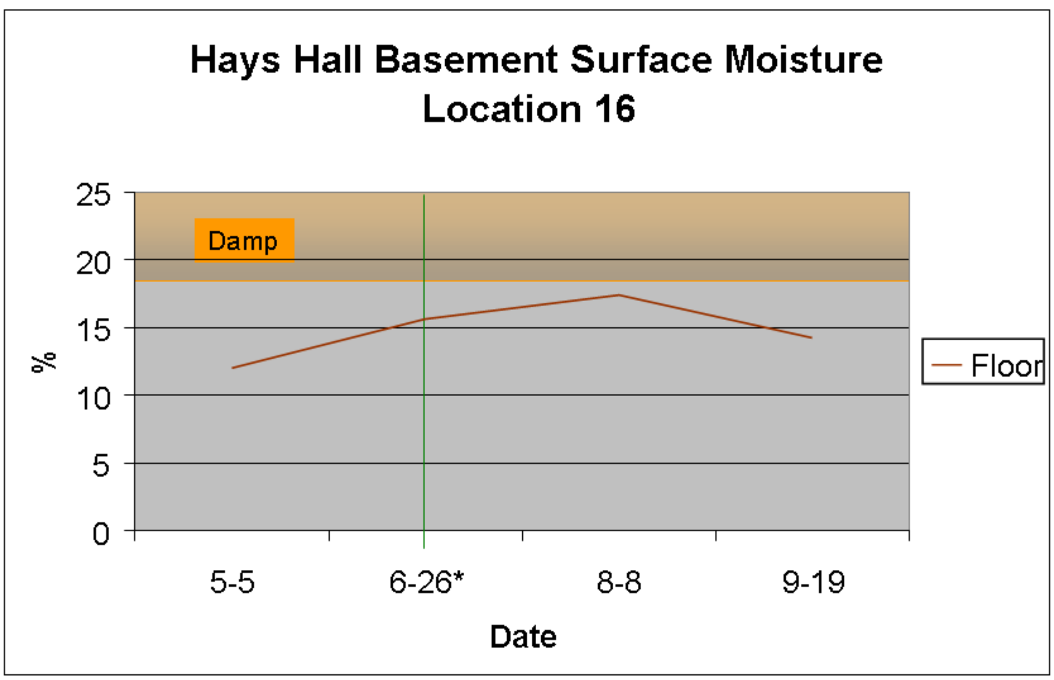


Figure B17. Plot of surface moisture vs time for Location 16.

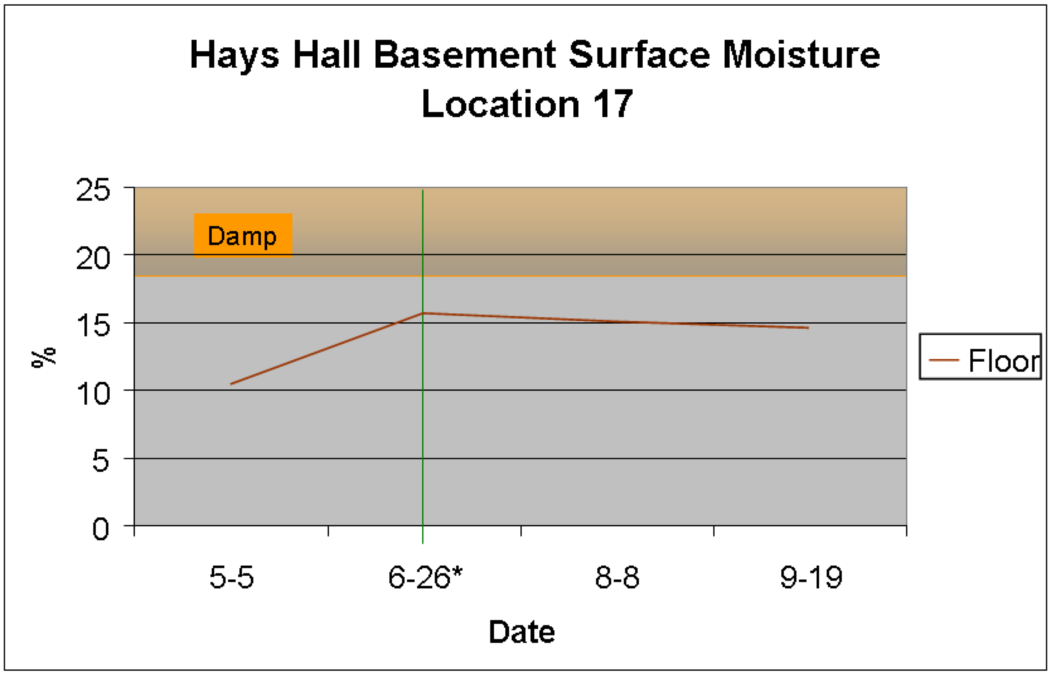


Figure B18. Plot of surface moisture vs time for Location 17.

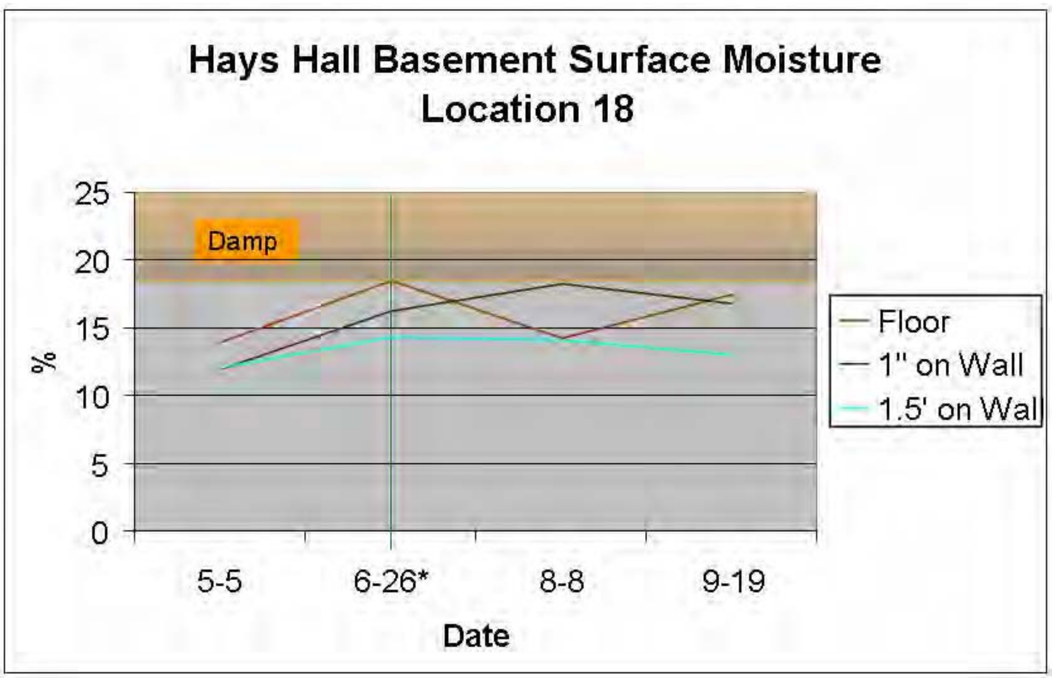


Figure B19. Plot of surface moisture vs time for Location 18.

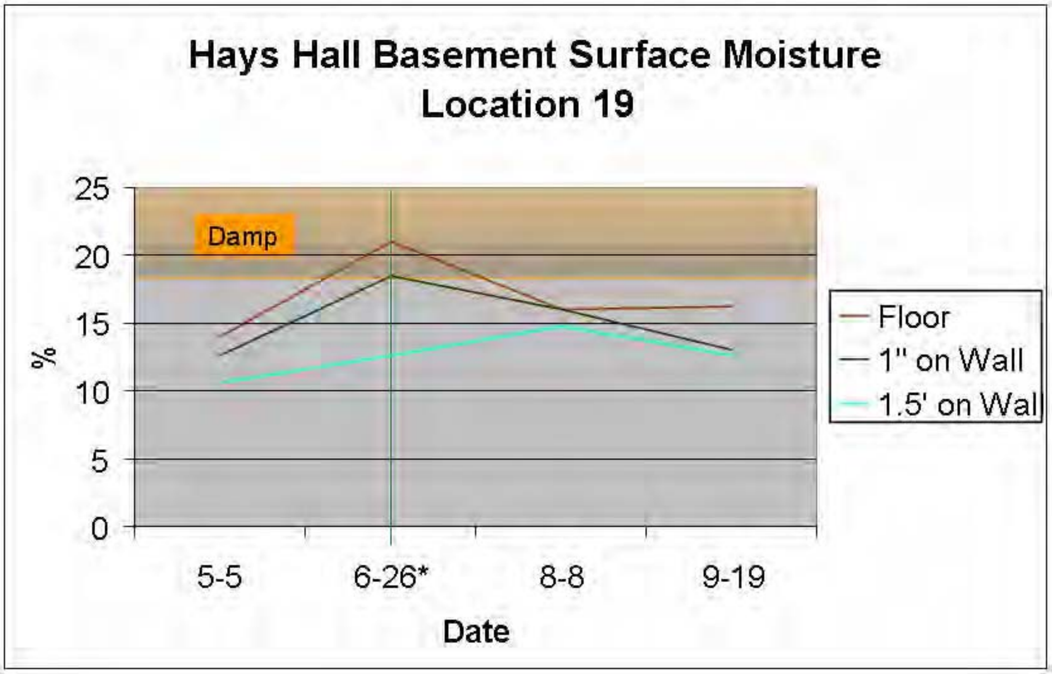


Figure B20. Plot of surface moisture vs time for Location 19.

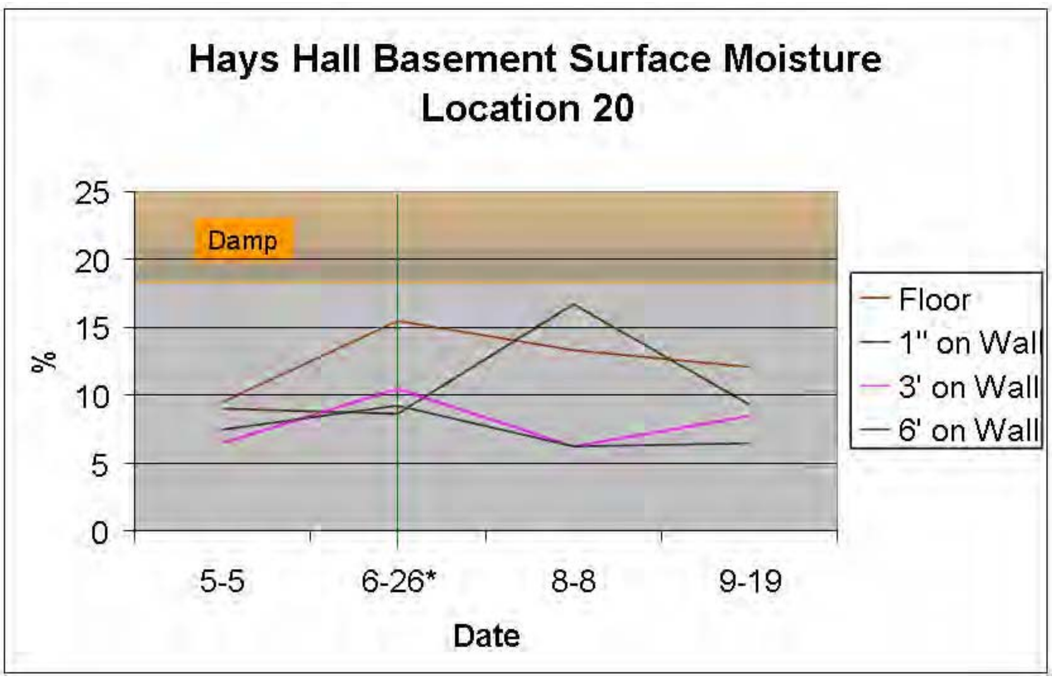


Figure B21. Plot of surface moisture vs time for Location 20.

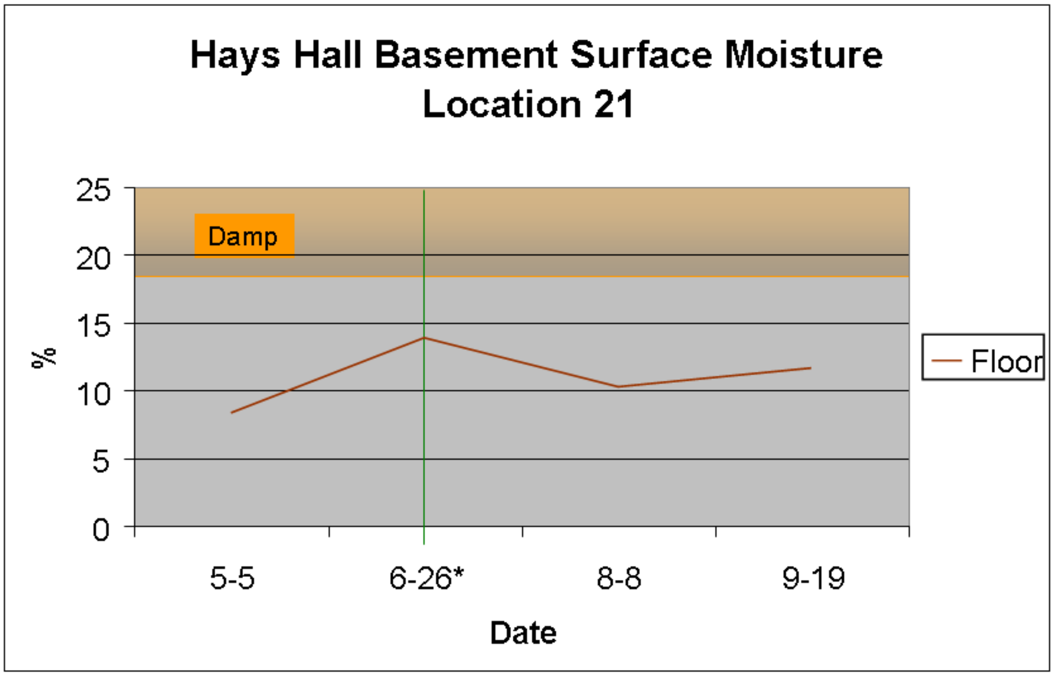


Figure B22. Plot of surface moisture vs time for Location 21.

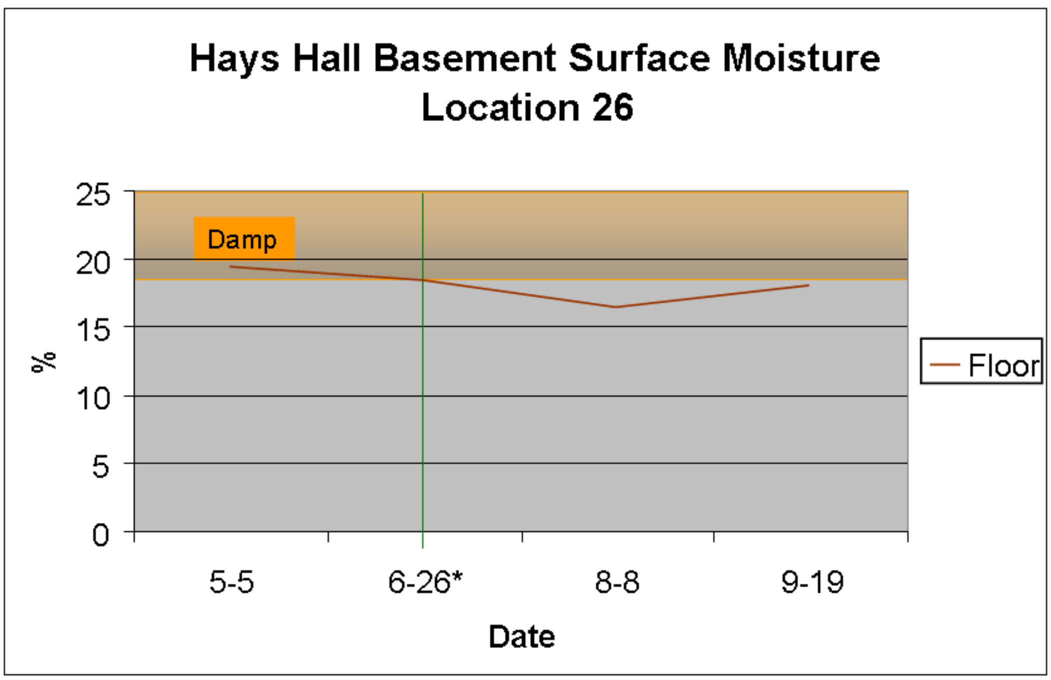


Figure B23. Plot of surface moisture vs time for Location 22.

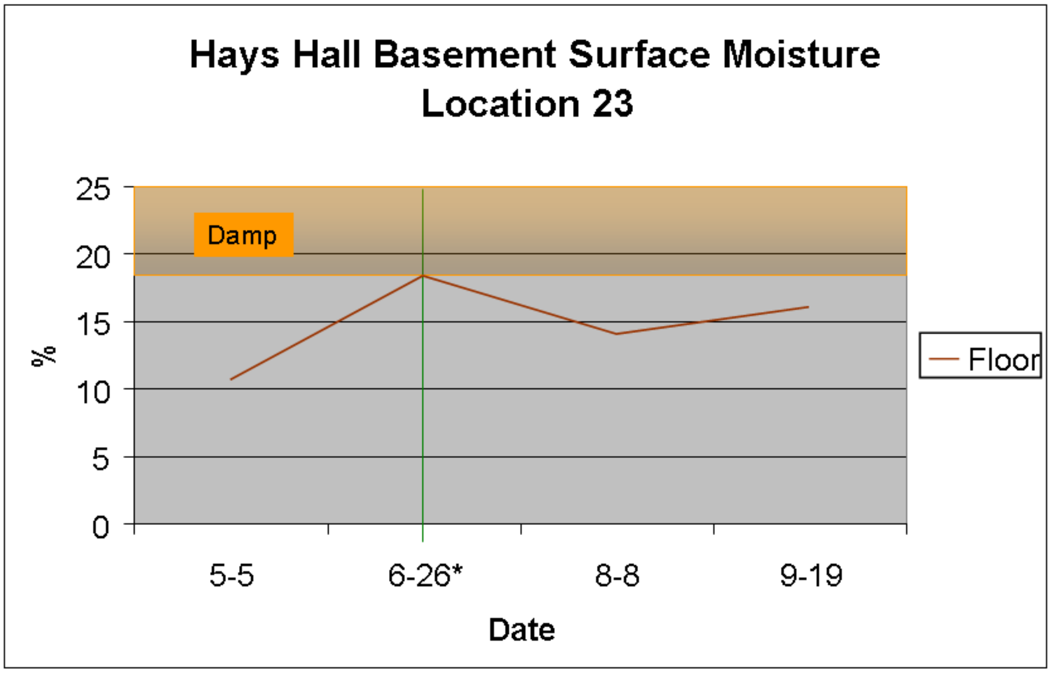


Figure B24. Plot of surface moisture vs time for Location 23.

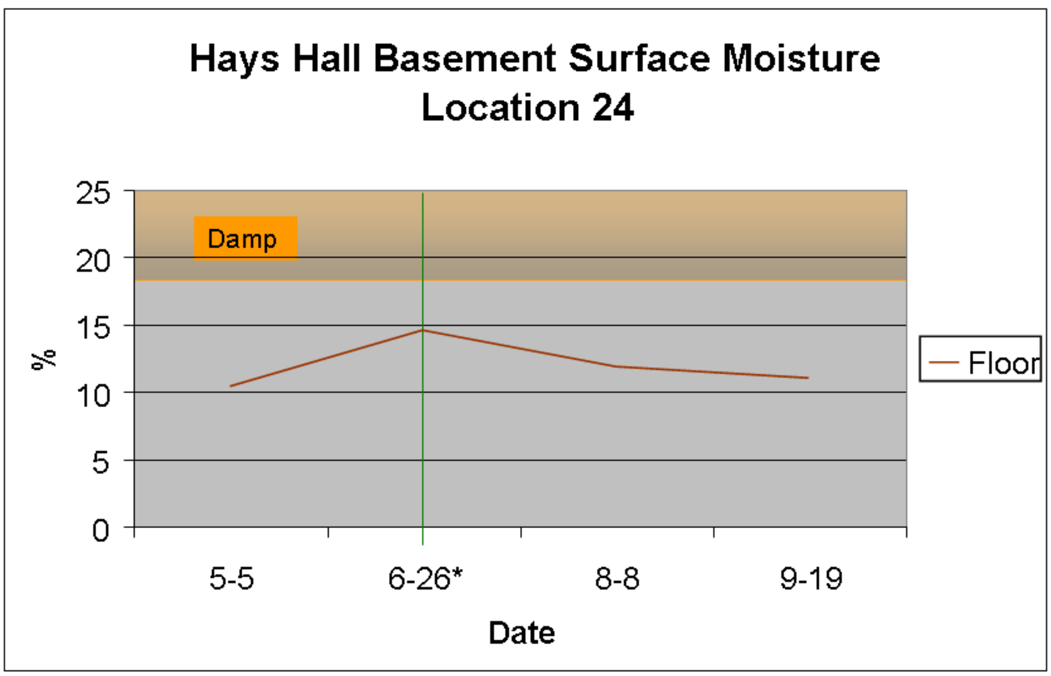


Figure B25. Plot of surface moisture vs time for Location 24.

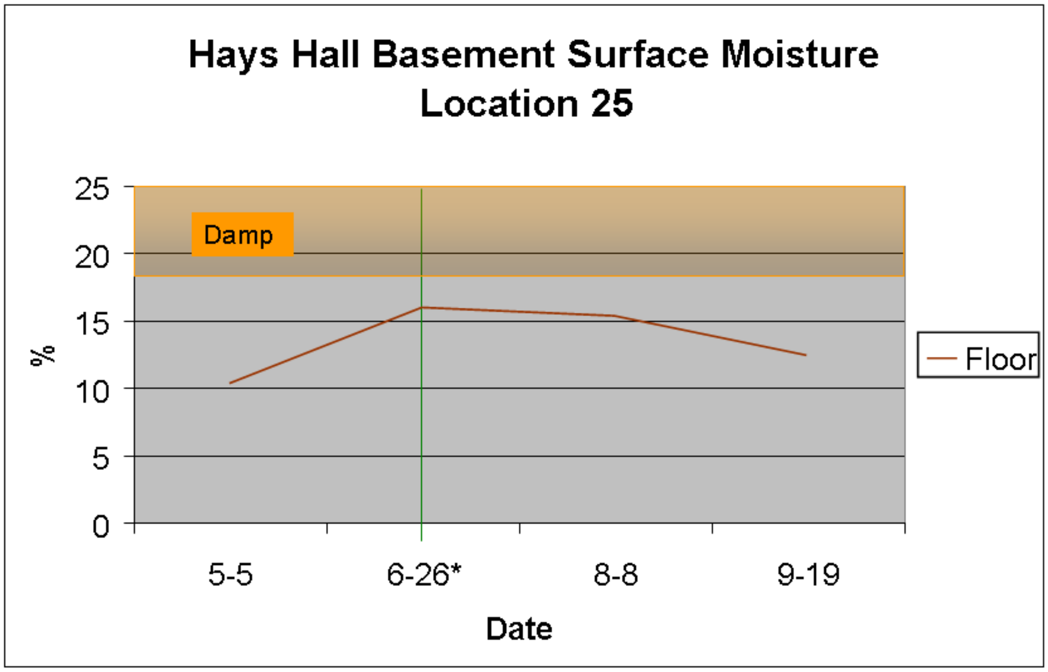


Figure B26. Plot of surface moisture vs time for Location 25.

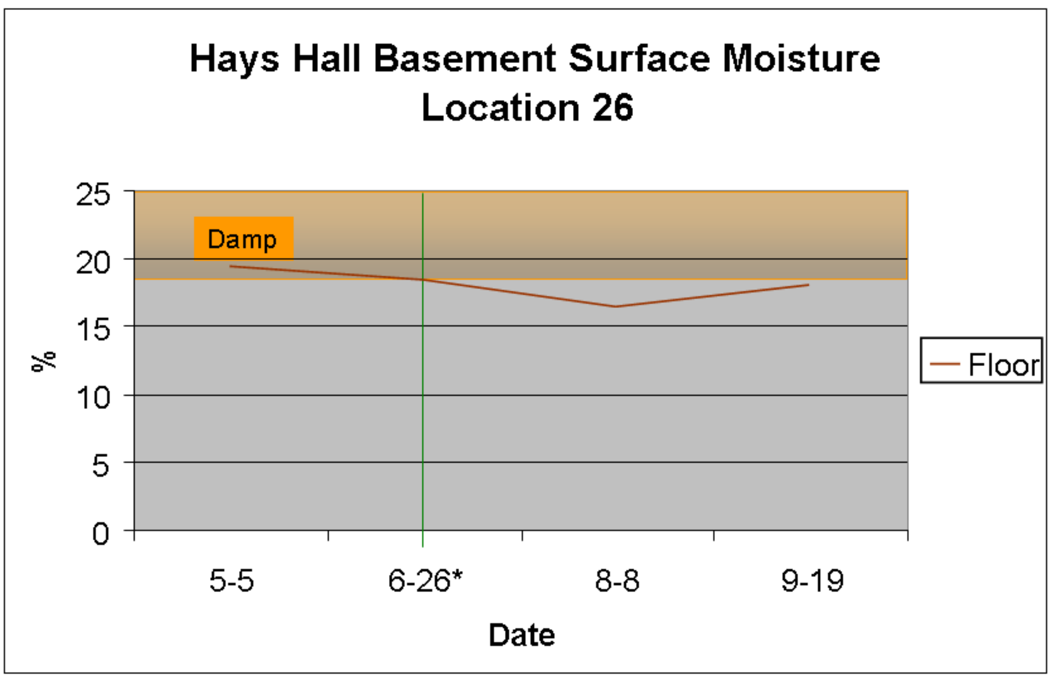


Figure B27. Plot of surface moisture vs time for Location 26.

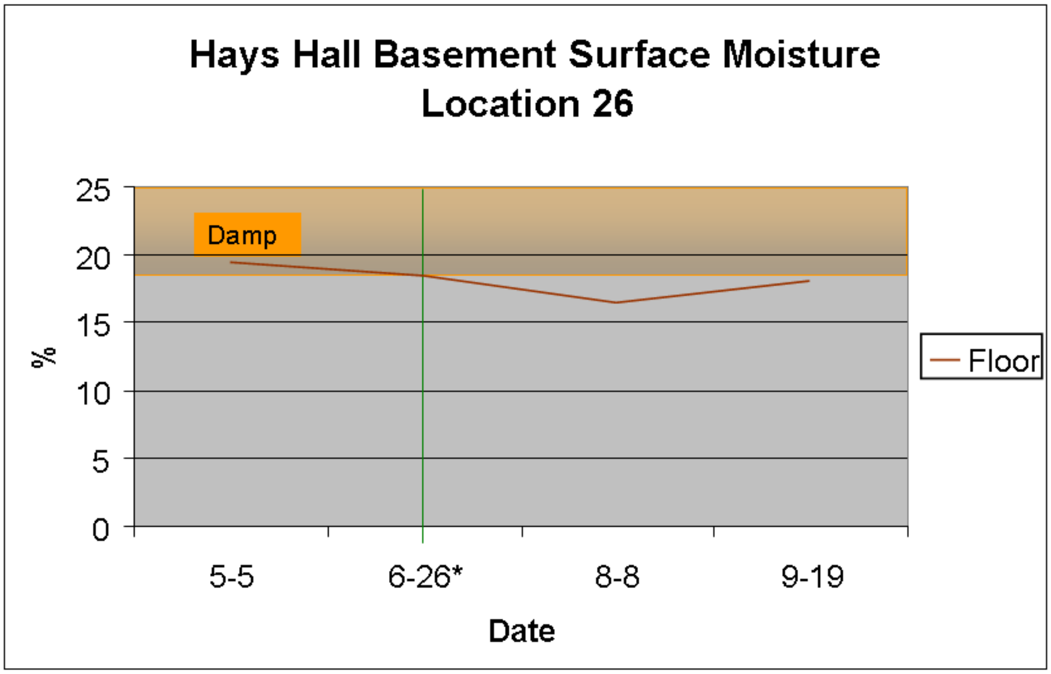


Figure B28. Plot of surface moisture vs time for Location 27.

Appendix C: EOP System Performance as Indicated by Temperature and Humidity Data

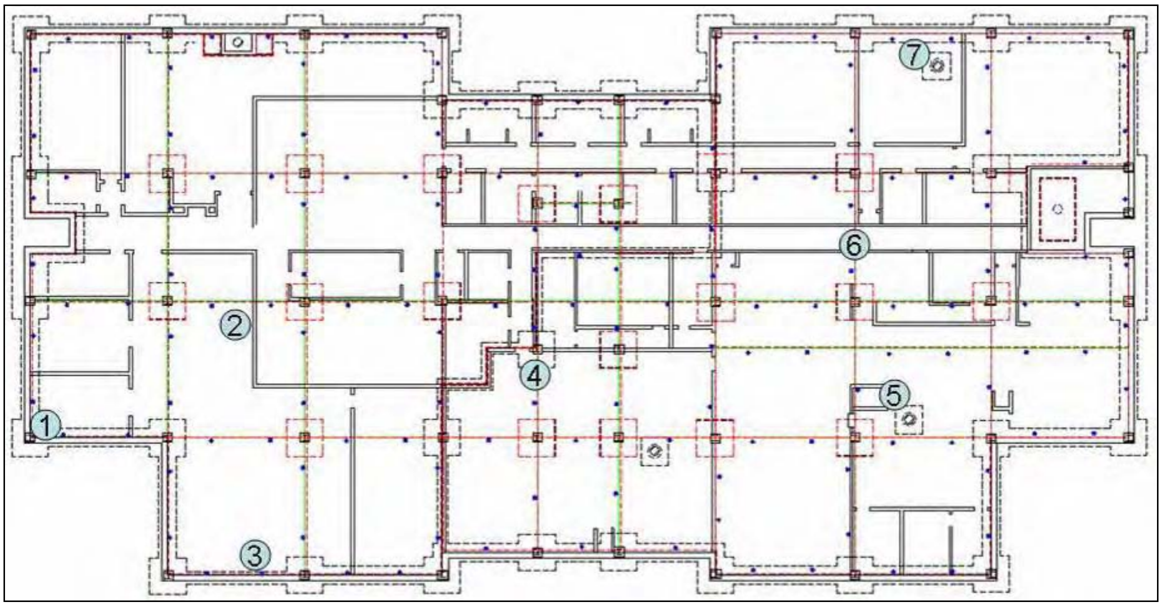


Figure C1. Temperature and relative humidity sampling locations.

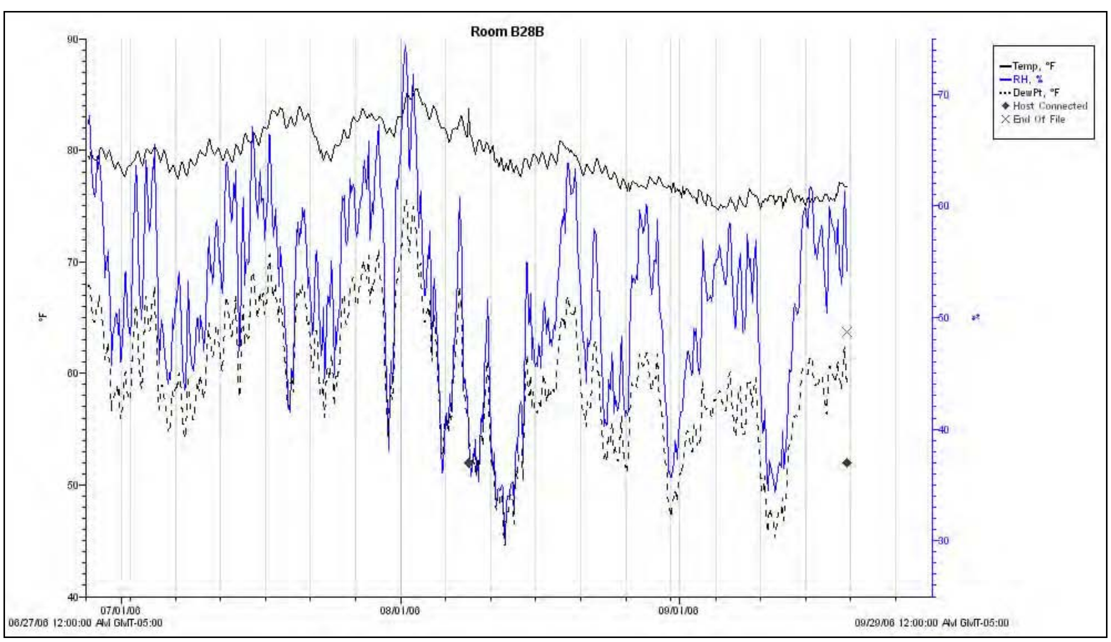


Figure C2. Plot of temperature, relative humidity, and dew point vs time for Location 1.

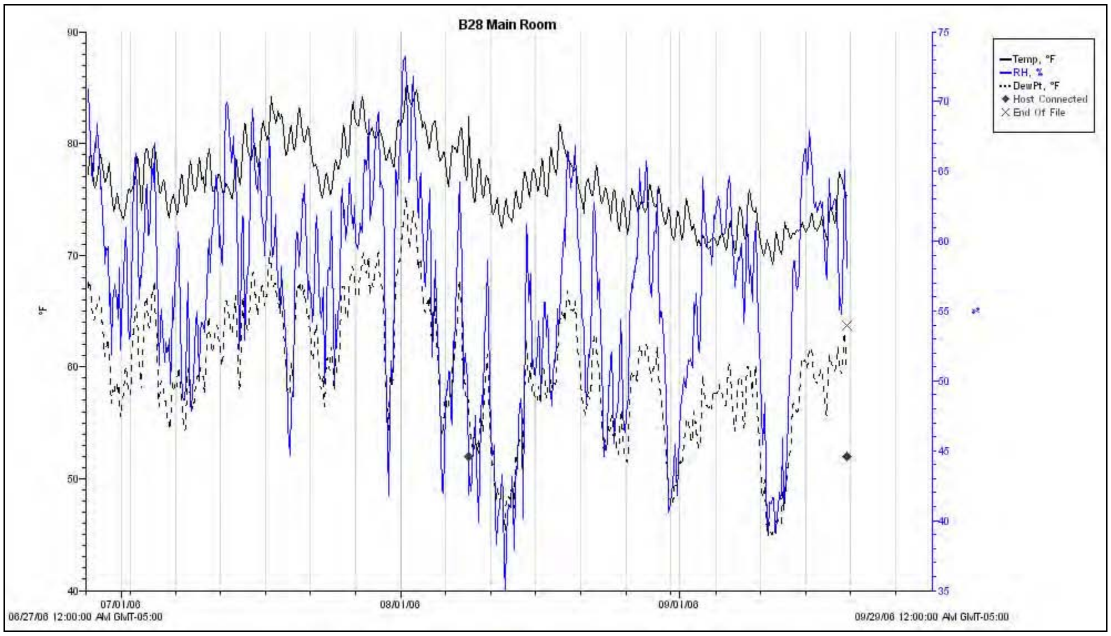


Figure C3. Plot of temperature, relative humidity, and dew point vs time for Location 2.

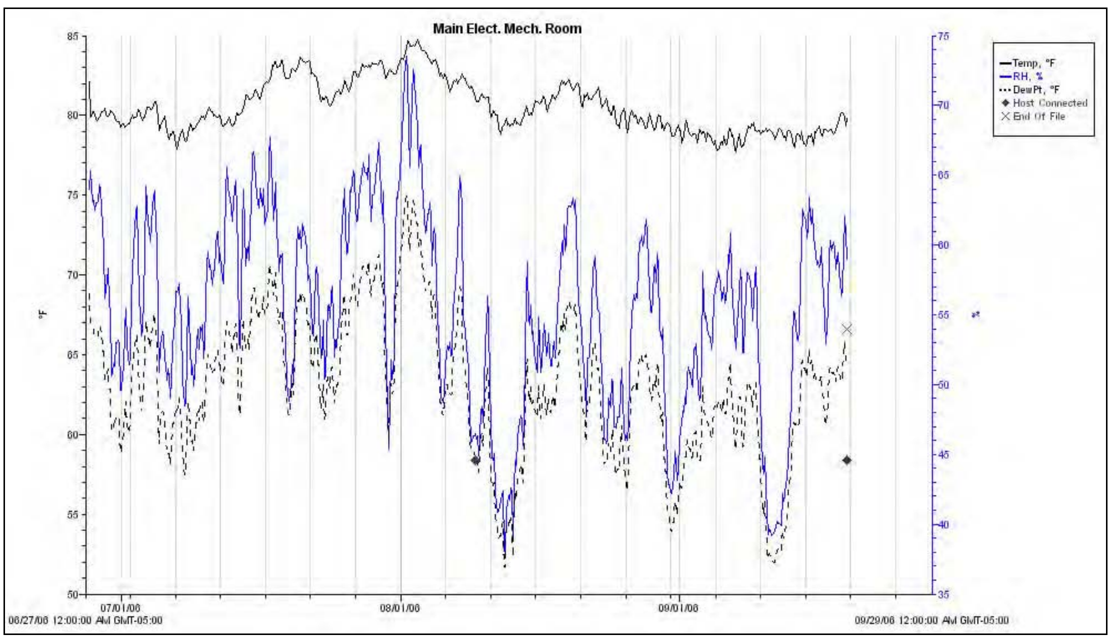


Figure C4. Plot of temperature, relative humidity, and dew point vs time for Location 3.

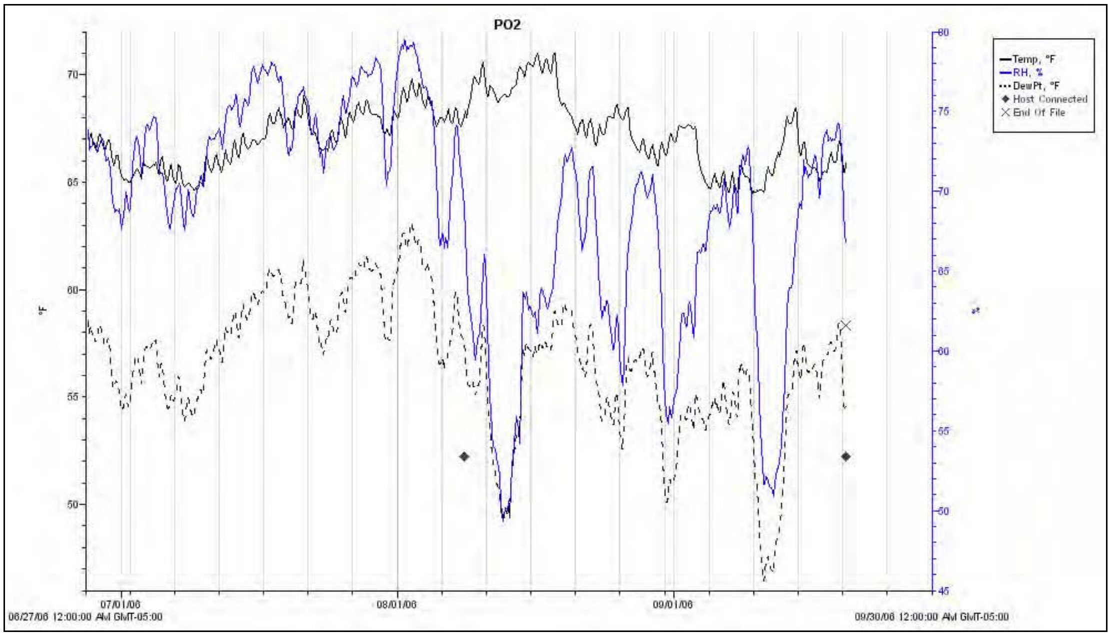


Figure C5. Plot of temperature, relative humidity, and dew point vs time for Location 4.

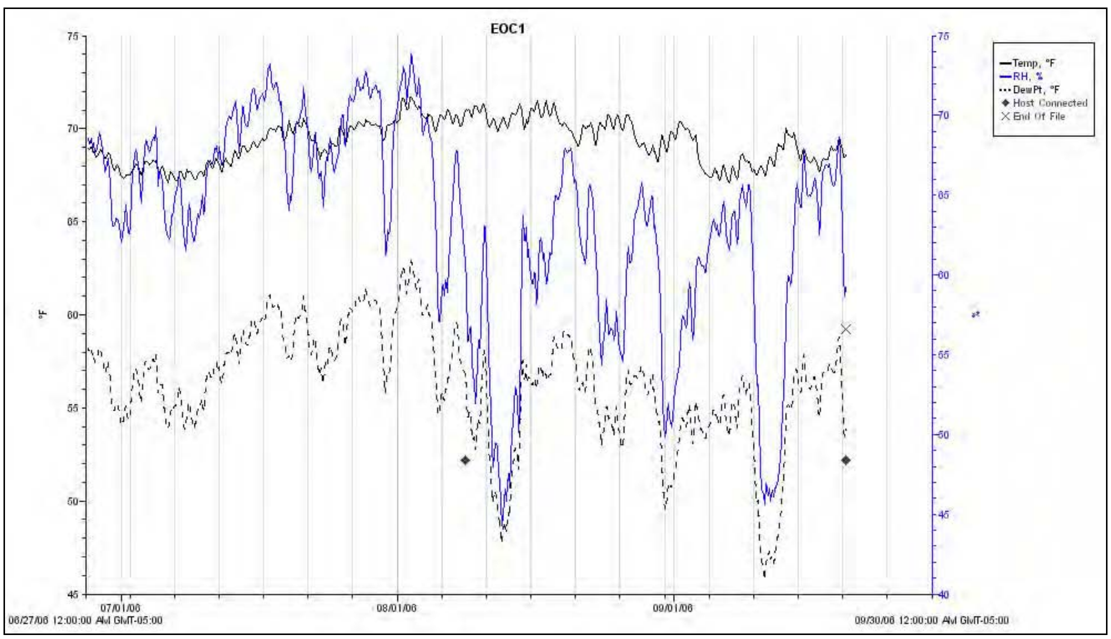


Figure C6. Plot of temperature, relative humidity, and dew point vs time for Location 5.

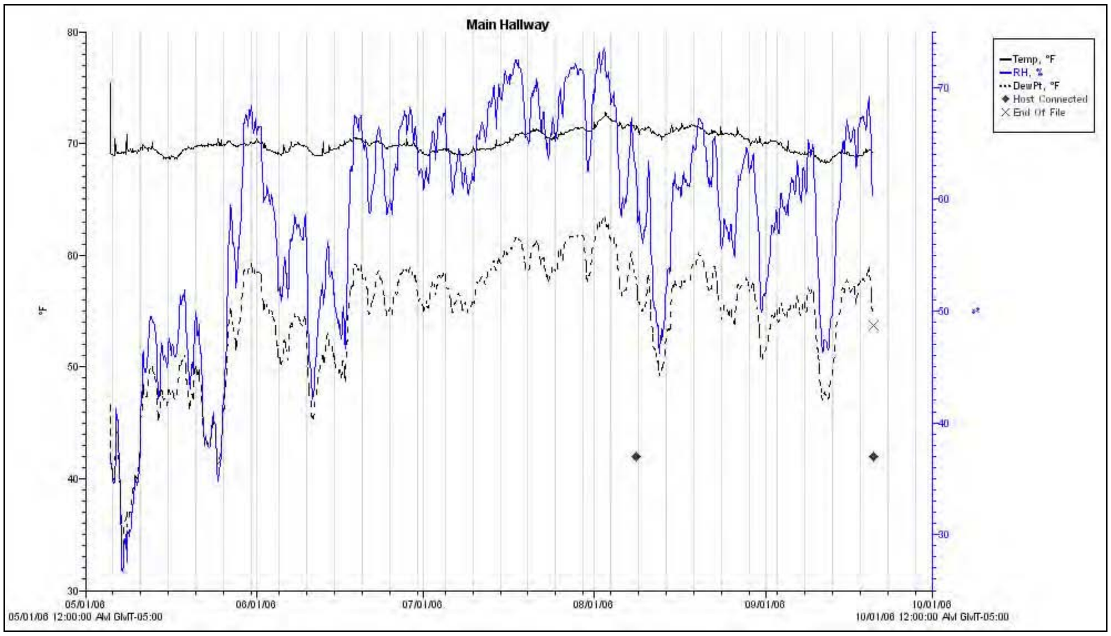


Figure C7. Plot of temperature, relative humidity, and dew point vs time for Location 6.

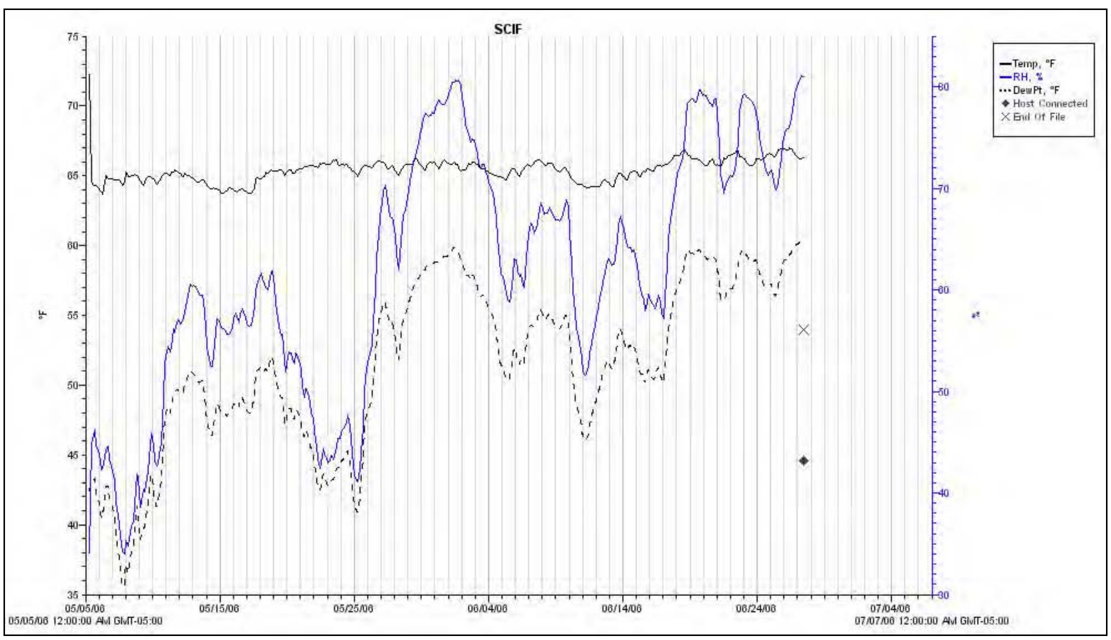
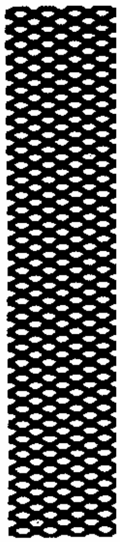
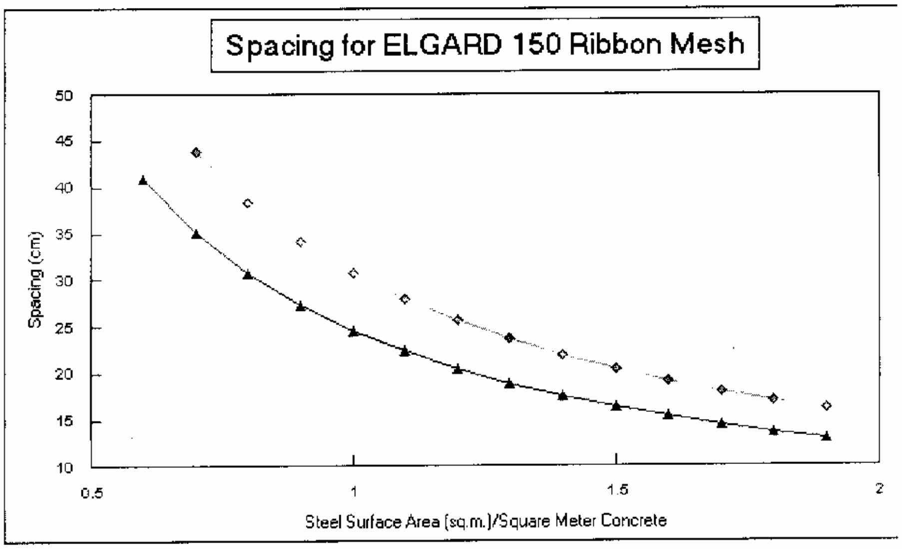


Figure C8. Plot of temperature, relative humidity, and dew point vs time for Location 7.

Appendix D: EOP Product Data Sheets





Actual Size

DESCRIPTION

ELGARD™ Anode Ribbon Mesh is a key component for Cathodic Protection systems in reinforced concrete structures. It is composed of a precious metal oxide catalyst sintered to an expanded titanium mesh substrate.

MATERIAL SPECIFICATIONS

Anode Performance:

Current rating at 110 mA/m^2 (10 mA/ft^2) .... 5.28 mA/m (1.61 mA/ft)
Expected life (NACE Standard TM02944-94) .... 75 years
Catalyst .... Mixed Metal Oxide
Maximum anode concrete interface current density:
..... FHWA limit .... 110 mA/m^2 (10 mA/ft^2)
..... Short-term limit .... 220 mA/m^2 (20 mA/ft^2)

Dimensions:

Width .... 19 mm (3/4")
Coil length .... 76 m (250 ft)

Figure D1:. Page 1 of anode product data sheet.

Actual anode surface per unit length of anode .... $0.048\ m^2/m$ ($0.157\ ft^2/ft$)
Expanded thickness .... 1.30 mm (0.051")
Diamond dimensions .... 2.5 mm x 4.6 mm x 0.6 mm (0.10" x 0.18" x 0.025")
Shipping weight per coil .... 2.7 kg (6 lbs)

Substrate:

Composition .... Titanium, Grade 1 per ASTM B265
Coefficient of thermal expansion .... 8.7×10^{-5}/°K (0.0000048/in/in/°K)
Thermal conductivity at 20°C .... 15.6 W/m^2-°K (9.0 BTU/hr/ft^2/°F/ft)
Electrical resistivity .... 0.000056 ohm-cm (0.000022 ohm-in)
Modulus of elasticity .... 105 GPa (14,900,000 PSI) minimum
Tensile strength .... 245 MPa (35,000 PSI) minimum
Yield strength .... 175 MPa (25,000 PSI) minimum
Elongation .... 24% minimum

Current Distributor:

Width .... 12.7 mm (1/2")
Thickness .... 0.9 mm (0.035")
Coil length .... 76 m (250 ft)
Shipping weight per coil .... 3.9 kg (8.6 lbs)

Electrical Properties:

Anode ribbon mesh resistance lengthwise .... 0.26 ohm/m (0.08 ohm/ft)
Current distributor resistance lengthwise .... 0.049 ohm/m (0.015 ohm/ft)

Figure D2. Page 2 of anode product data sheet.

BASF

The Chemical Company

PRODUCT DATA

3 03 36 00 **Grouts**

MASTERFLOW® 928

High-precision mineral-aggregate grout with extended working time

Description

Masterflow® 928 grout is a hydraulic cement-based mineral-aggregate grout with an extended working time. It is ideally suited for grouting machines or plates requiring precision load-bearing support. It can be placed from fluid to damp pack over a temperature range of 45 to 90° F (7 to 32° C). Masterflow® 928 grout meets the requirements of ASTM C 1107, Grades B and C, and the Army Corp of Engineers' CRD C 621, Grades B and C, at a fluid consistency over a 30-minute working time.

Yield

One 55 lb (25 kg) bag of Masterflow® 928 grout mixed with approximately 10.5 lbs (4.8 kg) or 1.26 gallons (4.8 L) of water, yields approximately 0.50 ft³ (0.014 m³) of grout.

The water requirement may vary due to mixing efficiency, temperature, and other variables.

Packaging

55 lb (25 kg) multi-wall paper bags

3,300 lb (1,500 kg) bulk bags

Shelf Life

1 year when properly stored

Storage

Store in unopened bags in clean, dry conditions.

Features	Benefits
• Extended working time	Ensures sufficient time for placement
• Can be mixed at a wide range of consistencies	Ensures proper placement under a variety of conditions
• Freeze/thaw resistant	Suitable for exterior applications
• Hardens free of bleeding, segregation, or settlement shrinkage	Provides a maximum effective bearing area for optimum load transfer
• Contains high-quality, well-graded quartz aggregate	Provides optimum strength and workability
• Sulfate resistant	For marine, wastewater, and other sulfate-containing environments

Where to Use

APPLICATION

- Where a nonshrink grout is required for maximum effective bearing area for optimum load transfer
- Where high one-day and later-age compressive strengths are required
- Nonshrink grouting of machinery and equipment, baseplates, soleplates; precast wall panels, beams, columns; curtain walls, concrete systems, other structural and nonstructural building members; anchor bolts, reinforcing bars, and dowel rods
- Applications requiring a pumpable grout
- Repairing concrete, including grouting voids and rock pockets
- Marine applications
- Freeze/thaw environments

LOCATION

- Interior or exterior

How to Apply

Surface Preparation

1. Steel surfaces must be free of dirt, oil, grease, or other contaminants.
2. The surface to be grouted must be clean, SSD, strong, and roughened to a CSP of 5 – 9 following ICRI Guideline 03732 to permit proper bond. For freshly placed concrete, consider using Liquid Surface Etchant (see Form No. 1020198) to achieve the required surface profile.
3. When dynamic, shear or tensile forces are anticipated, concrete surfaces should be chipped with a "chisel-point" hammer, to a roughness of (plus or minus) 3/8" (10 mm). Verify the absence of bruising following ICRI Guideline 03732.
4. Concrete surfaces should be saturated (ponded) with clean water for 24 hours just before grouting.
5. All freestanding water must be removed from the foundation and bolt holes immediately before grouting.
6. Anchor bolt holes must be grouted and sufficiently set before the major portion of the grout is placed.

Protection and Repair

Figure D3. Floor grout product data sheet.

STRATA-TECH, INC.

Return to ST-524

ST-524

POLY-FOAM INJECTION RESIN

INTRODUCTION

Stratathane ST-524 Poly-Foam is a hydrophobic two component, flexible polyurethane resin based on MDI in combination with high-value polyether polyols. ST-524 Poly-Foam reacts with water and sets into a flexible closed-cell foam. ST-524 is mixed with ST-525 at the work site to form a single injection material whose reaction time is governed by the concentration of ST-525 in the blend.

The ST-524/525 mix reacting with water forms an inert barrier which is essentially unaffected by acids, gasses, and micro-organisms usually found in soil or the leak area. A minimum of reaction water is needed but larger amounts can be accommodated through displacement.

ST-524 is useful for a wide range of water control applications, including formation of grout curtains, stabilization of water-bearing soils, and sealing of cracks and joints in concrete, buildings, dams, and utility vaults.

ST-524 has NSF 61 approval for potable water contact and carries the Underwriters Laboratories UL seal.

ST-524 is injected directly from the can into the leak using either a single or a plural component high pressure pump. When 20 parts of ST-524 react with one part of water, the resulting mixture expands and quickly fills the leak path with an elastic seal that stops water entry but allows crack movement to protect against stress transfer. Concrete repaired with ST-524 will usually not crack again.

Stainless steel fittings are recommended but not strictly required because the ST-524/525 blend is only mildly corrosive. Cleanup of solidified material in the system, however, is often accomplished with caustic cleaning compounds, making stainless steel advisable.

The low-viscosity ST-524 mixture is easily injected. Once cured, its impermeability makes it an effective water shut-off system. The permeability of soil grouted with ST-524 depends on how well its voids are filled with grout. Values in the 10-5 cm/sec range should be obtained using ASTM Constant Head Permeability Test Method D-2434.

REACTION

A two stage reaction takes place when ST-524 comes in contact with water. The mixture first expands and quickly thickens. Then, as it cures, ST-524 solidifies into a strong impermeable water barrier in just minutes. Unrestrained ST-524 foam expands up to ten times its starting volume. However, a dense material is preferred for most applications. Greater density is obtained by controlling grout placed relative to void space and static head pressure.

The two stage reaction takes place continuously during injection as product exits the packer. Initial penetration is facilitated by the low viscosity of the mixture. After reaction begins, the expansive mixture pressure induces some further penetration of the grout zone depending on the amount of static head pressure. ST-524 creates a seal which is impervious to water yet is able to tolerate freeze-thaw, wet-dry cycling, extrusion, and compression.

CURE

The reaction and set time of ST-524 resin is a function of both temperature and the concentration of ST-525 in the blend. The following table shows the effect of ST-525 at different weight percentages at a temperature of 20C.

ST-525 WT %	CREAM TIME (SECONDS)	TACK FREE (MINUTES)
1.0	100	25.0
2.0	70	14.0
3.0	40	7.0
6.0	35	3.2
10.0	29	3.0

3601 104th Street Des Moines, Iowa 50322 PHONE 515/251.7770 FAX 515/251.7705
WEB SITE www.strata-tech.com EMAIL Info@strata-tech.com

CHEMICAL SEALANTS • WATER CONTROL MATERIALS • GROUTING EQUIPMENT

Figure D4. Page 1 of polyurethane injection resin product data sheet.

STRATA-TECH, INC.

PHYSICAL CONSTANTS

The primary physical constants for the ST-524 system are shown in the table which follows.

	ST-524	ST-525
Appearance	Pale Yellow	Greyish Liquid
Specific Grav	1.08 20 C	0.995 at 20 C
Viscosity	500 cps 25 C	25 cps at 25 C
Flash Point	>385 C	130 C

The low viscosity of the ST-524 Resin blend allows good penetration into cavities and cracks. After curing, water pressure will not affect the ST-524 resin seal at heads usually encountered in crack injection repair work. It has no preset "pot life" and does not cure as long as water or moisture vapor are not available to start the cure cycle.

TENSILE AND ELONGATION

Test samples were prepared by putting the reacting mixture into a plastic pressure mold and capping the opening. This procedure (per ASTM D-638) resulted in a closed-cell foam with a density of about 30 pounds per cubic foot as compared to a free rise density of about 6 pounds per cubic foot. Measured tensile strength was about 6 psi at 67% elongation. The samples subsequently showed no water absorption after 4 hour immersion. Flammability tests of the same samples showed that combustion self-extinguished when the flame source was removed.

To prevent condensation from forming on the liquid or in the can, the temperature of the ST-524 should be adjusted to match the ambient temperature of the work area. Protect uncured resin during application from exposure to water, moisture vapor, and direct sunlight.

CLEANUP

Cleanup of ST-524 is accomplished with a solvent or with a solvent and a cleaner used in sequence. The preferred solvent is ST-590 Kleen-Purge and the recommended cleaner is ST-522 Veri-Kleen Grout Cleaner. Use ST-590 for the liquid resin and ST-522 for solidified resin.

For heavy cleaning, push out ST-590 with ST-522 Veri-Kleen Grout Cleaner and follow the instructions for its use. Do not allow ST-590 or ST-522 to remain in the system for long periods. Properly dispose of used cleaning materials and do not reuse if contaminated or resin-loaded. See the pump manuals and the Technical Data Sheet for ST-522 and ST-590 for more information.

ENVIRONMENTAL

ST-524 is essentially non-toxic in its cured form, with an LD50 (rat) in excess of 5000 mg/kg. Freezing either the cured or uncured material is not harmful to the product and may prolong the shelf life of the uncured resin in an unopened container. At temperatures below 5 C, crystallization may occur but is reversible without damage to the material by indirectly warming and gently mixing the product.

Stratathane ST-524 contains no measurable amount of TDI as performed by the Modified Analysis for Diisocyanates. ST-524 is non-flammable, non-carcinogenic, and non-corrosive as defined by 40 CFR and as described in the *NIOSH Pocket Guide for Hazardous Materials.*

Back to ST-524 Urethane Grout

STATEMENT

Strata Tech believes that the information herein is an accurate description of the general properties and characteristics of the product(s), but the user is responsible for obtaining current information because the body of knowledge on these subjects is constantly enlarged. Information herein is subject to change without notice. Field conditions also vary widely, so users must undertake sufficient verification and testing of the product or process herein to determine performance, safety, usefulness, and suitability for their own particular use.

Strata Tech warrants only that the product will meet Strata Tech's then-current specification. NO WARRANTY OF SUITABILITY OR FITNESS FOR A PARTICULAR PURPOSE IS MADE. Users should not assume that all safety requirements for their particular application(s) have been indicated herein and that other or additional actions and precautions are not necessary. Users are responsible for always reading and understanding the Material Safety Data Sheet, the product technical literature, and the product label before using any product or process mentioned herein and for following the instructions contained therein.

3601 104th Street Des Moines, Iowa 50322 PHONE 515/251.7770 FAX 515/251.7705
WEB SITE www.strata-tech.com EMAIL Info@strata-tech.com

CHEMICAL SEALANTS • WATER CONTROL MATERIALS • GROUTING EQUIPMENT

Figure D5. Page 2 of polyurethane injection resin product data sheet.

COPPER BONDED GROUND RODS

Copper Bonded Ground Rods

- Galvan's copper bonded rods have a heavy, uniform coating of copper metallurgically bonded to a rigid steel core.
- UL Listed rods have 10mil minimum copper plating. UL/RUS models have 13mils of copper.
- Galvan manufactures copper-clad rods under patent 6,527,934

Catalog Number	Nominal Diameter X Length	Sub & Master Bundle	Wt. per 100	NAED UPC No. 632591-
3754	3/8" x 4'	10 / 100	132	61384-2
3755	3/8" x 5'	10 / 100	165	61385-9
3756	3/8" x 6'	10 / 100	200	61386-6
5005	1/2" x 5'	5 / 100	305	61125-1
5006	1/2" x 6'	5 / 100	370	61126-8
5008	1/2" x 8'	5 / 100	500	61128-2
5008L*	1/2" x 8'	5 /100	545	61138-1
5010	1/2" x 10'	5 / 100	611	61120-6
5010L*	1/2" x 10'	5 / 100	690	61130-5
6254	5/8" x 4'	5 / 100	340	-
6255	5/8" x 5'	5 / 100	424	61585-3
6256	5/8" x 6'	5 / 100	508	61586-0
6258*	5/8" x 8'	5 / 100	680	61588-4
6258G13**	5/8" x 8'	5 / 100	700	61217-3
6260*	5/8" x 10'	5 / 100	847	61580-8
6260G13**	5/8" x 10'	5 / 100	860	61218-0
7508*	3/4" x 8'	5 / 50	992	61548-8
7510*	3/4" x 10'	5 / 50	1240	61340-8
1010*	1" x 10'	25	2248	61440-5

Notes:

*These rods are UL Listed

**These rods meet the requirements of UL & RUS (13 mils mimimum of copper).

Rods with less than 10 mils of copper, do not meet UL requirements, nor the NEC Code.

Figure D6. Cathode product data sheet.

MICOR

PRODUCT DATA
MICOROX® JOINT FILLER

MICOROX™ Joint Filler (J.F.) is a two component, 100% solids epoxy resin based product designed to fill non-moving cracks and joints in concrete surfaces. **MICOROX® "J.F."** is a semi flexible liquid product that penetrates cracks and provides support to joint edges in traffic aisles.

AREAS OF APPLICATION:

- Concrete floors
- Secondary containment areas
- Warehouses
- Industrial facilities
- Paper Mills
- Food Processing Plants

FEATURES:

- Economic
- 1 to 1 Mix Ratio
- Protects joint edges
- Low temperatures brittle point
- Easy to place and trim

PACKAGING:

2 Gallon Units
20 Gallon Units

COVERAGE PER GALLON:

25 Lineal Feet - 1" wide x 3/4" deep
38 Lineal Feet - 1/2" wide x 1" deep
77 Lineal Feet - 1/4" wide x 1" deep

PHYSICAL/CHEMICAL CHARACTERISTICS:

Viscosity: 3000 CPS Mixed

Yield: 231 cubic inches per mixed gallon

Color: Grey, other colors by request

Working Life-Mixed Materials 25-30 minutes

Set Time. . . . 5 to 8 hours at 70°
Tensile Strength. . . 500 psi
Tensile Elongation . . . 110%
Compressive Strength . . .7600 psi
Tensile Bond Strength . . . 350 psi

STORAGE AND SHELF LIFE:
Stored at room temperature, the unopened materials should have a shelf life of one year.

MICOR CO., INC. • 3232 NORTH 31ST ST. • MILWAUKEE, WI 53216 • PHONE [414] 873-2071 1-800-284-4308

Figure D7. Page 1 of joint filler product data sheet.

SURFACE PREPARATION:
Cracks and voids must be clean and free of loose material, dust, grease, oil, grout, or other contaminants. Chip or rout out cracks that are hard to clean. Notch or V cracks for maximum performance. Seal the bottoms of cracks through the slab, or where the Joint Filler will leak through, with a polyurethane rope. Concrete should be clean, dry and rough for best performance.

APPLICATION INSTRUCTIONS:

Mix **MICOROX® Joint Filler** by combining one part of hardener component with one part of resin component. A measuring cup, or a can may be used to measure the components.

Mix the two components together thoroughly for two to three minutes to a uniform color and consistency. Use a paddle or low speed drill - stirrer to mix the material.

To apply the material. a plastic squeeze bottle (like a ketchup bottle) works well. Dispense the liquid into the crack until penetration stops and the crack is full. To fill very fine cracks, pressure is required to force the sealer into place. A grease gun with grease fittings may be used. Pressure injection devices may also be used. Contact Micor for recommendations.

The **MICOROX® Joint Filler** may be thickened for application on vertical cracks. Mix the material as described above and add the dry thickening agent (sold seperately) to obtain the desired consistancy. Apply with a squeeze bottle, spatula, trowel or with pressure equipment.

6/6/95

CLEAN UP:
Clean tools immediately with hot soapy water or with solvents such as Xylene or MEK. These products are **HAZARDOUS** and must be used with **CAUTION** and **MUST** be used with appropriate **VENTILATION.** See their M.S.D.S. sheets for appropriate use.

WORKING LIFE:
Working life of mixed materials is very short. Mix only the amount of material that can be used in 30 minutes.

HANDLING PRECAUTIONS:
MICOROX® Joint Filler is intended for industrial and commercial use only! Prolonged contact with skin can cause irritation. **Wear protective clothing and chemical splash goggles to avoid eye contact. NEVER RECAP A CONTAINER OF MIXED COMPONENTS** as the continuing reaction may cause an **EXPLOSION.** READ THE M.S.D.S. SHEET BEFORE USING.

COMPLIMENTARY INFORMATION:
Our full service lab and technical engineers are available to assist you. For complete information on all systems, contact your local Dealer or our factory at 1-800-284-4308.

Micor Company, Inc. believes the information contained herein to be true and accurate. Information contained herein is for evaluation purposes only. Micor makes no warranty, express or implied based upon this literature and assumes no liability or responsibility for consequential or incidental damages as a result of the use of these products and systems described herein, including any warranty of merchantability or fitness.

THIS MATERIAL IS INTENDED FOR INDUSTRIAL USE ONLY!

Figure D8. Page 2 of joint filler product data sheet.

CADWELD® PLUS ONE SHOT Page 1 of 2

ERICO

CADWELD® PLUS ONE SHOT

CADWELD

The CADWELD® PLUS ONE SHOT produces a pemanent exothermic connection to a ground rod that will not loosen, corrode or increase in resistance for the life of the installation. The convenient single-use package makes the connection to the ground rod without a mold or starting material. Thanks to the electronic CADWELD PLUS Control Unit, welds can now be completed up to 6 feet (1.8 meters) away, increasing flexibility in hard-to-reach areas. The new refractory ceramic body utilized with the CADWELD PLUS ONE SHOT system is more durable than conventional ceramic and resists breaking.

Features

- Easy-to-use electronic ignition. No starting material.
- Durable disposable ceramic body eliminates the graphite mold and frame.
- Produces a permanent connection that will not loosen or corrode.
- NEC® compliant.
- cULus® Listed.

Applications

The CADWELD PLUS ONE SHOT is ideal for making permanent reliable connections to ground rods for electrical transmission and distribution, telecommunications and cable television applications.

More Information

CADWELD PLUS ONE SHOT part numbers for type GR (one conductor to ground rod) and type GT (two conductors to ground rod) connections:

GROUND ROD	CONCENTRIC CONDUCTOR		METRIC CONDUCTOR	CADWELD PLUS ONE SHOT PART NUMBER	
	SOL	STR	SQUARE MILLIMETER	TYPE GR	TYPE GT
1/2" (12.7mm)	6, 8 3, 4 1, 2	8 4, 6 2, 3	8 - 10 14 - 22 30 - 38	GR1141GPLUS GR1141LPLUS GR1141VPLUS	GT1141GPLUS GT1141LPLUS GT1141VPLUS
5/8" (14-16mm)	6, 8 3, 4 1, 2 2/0, 1/0	8 4, 6 2, 3 1/0, 1 2/0 4/0	8 - 10 14 - 22 30 - 38 50 - 60 70	GR1161GPLUS GR1161LPLUS GR1161VPLUS GR1162CPLUS GR1162GPLUS GR1162QPLUS	GT1161GPLUS GT1161LPLUS GT1161VPLUS GT1162CPLUS GT1162GPLUS -
3/4" (17-19mm)	6, 8 3, 4 1, 2 2/0, 1/0	8 4, 6 2, 3 1/0, 1	8 - 10 14 - 22 30 - 38 50 - 60	GR1181GPLUS GR1181LPLUS GR1181VPLUS GR1182CPLUS	GT1181GPLUS GT1181LPLUS GT1181VPLUS GT1182CPLUS

Figure D9. Page 1 of exothermic weld device product data sheet.

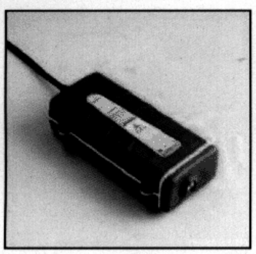
CADWELD® PLUS ONE SHOT Page 2 of 2

		2/0 4/0	70	GR1182GPLUS GR1182QPLUS	GT1182GPLUS -

CADWELD PLUS ONE SHOT part numbers for type NT (three conductors to ground rod) and type NX (four conductors to ground rod) connections:

GROUND ROD	CONCENTRIC CONDUCTOR		METRIC CONDUCTOR	CADWELD PLUS ONE SHOT PART NUMBER	
	SOL	STR	SQUARE MILLIMETER	TYPE NT	TYPE NX
1/2" (12.7mm)	6, 8 3, 4 1, 2	8 4, 6 2, 3	8 - 10 14 - 22 30 - 38	NT1141GPLUS NT1141LPLUS NT1141VPLUS	NX1141GPLUS NX1141LPLUS -
5/8" (14-16mm)	6, 8 3, 4 1, 2 2/0, 1/0	8 4, 6 2, 3 1/0, 1 2/0 4/0	8 - 10 14 - 22 30 - 38 50 - 60 70	NT1161GPLUS NT1161LPLUS NT1161VPLUS	NX1161GPLUS NX1161LPLUS NX1161VPLUS
3/4" (17-19mm)	6, 8 3, 4 1, 2 2/0, 1/0	8 4, 6 2, 3 1/0, 1 2/0 4/0	8 - 10 14 - 22 30 - 38 50 - 60 70	NT1181GPLUS NT1181LPLUS NT1181VPLUS	NX1181GPLUS NX1181LPLUS NX1181VPLUS

The CADWELD PLUS Control Unit, which is required to initiate the reaction, is ordered separately.



PLUSCU

Figure D10. Page 2 of exothermic weld device product data sheet.

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Current refinements (click ☒ to remove)

☒ **Region › USA** ☒ **Product Line › Heat Shrink & Abrasion Protection** › ☒ **Heat Shrink ›**
☒ **Thick Wall Adhesive Lined Polyolefin and End Caps for Wet Locations** ☒ **Product Family ›**
Thick Wall Polyolefin Heat Shrink

- Shrink ratio of 3:1 insulates a wide range of diameters and irregular shapes, which red costs
- Cross-linked, UV resistant material improves flame retardancy, chemical, and tempera
- Thick wall product seals and insulates in one step to speed installation

* For red, add 2 to end of part number package suffix (Example HST0.4-3-Q2).
‡‡ Meets Mil Spec AMS-DTL-23053/15 Class 1.

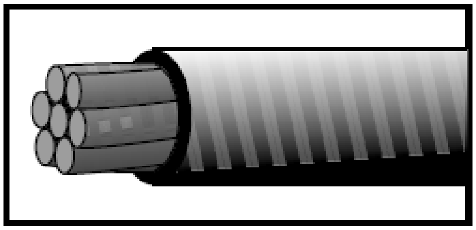
Part Number:	HST0.4-48-5
Product Family:	Thick Wall Polyolefin Heat Shrink
Product Line:	Accessories
Product Line:	Thick Wall Adhesive Lined Polyolefin and End Caps for Wet Locations
RoHS Compliancy Status:	Compliant
Part Description:	Thick Wall Heat Shrink provides excellent protection above or below ground level and is suital locations and direct burial (UL486D)
Material:	Flame retardant polyolefin cross-linked with adhesive‡‡
Color:	Black
CSA Certified:	Yes
Military Specification:	AMS-DTL-23053/15 Class 1
UL Recognized:	Yes
Length (In.):	48.00
Length (mm):	1200.0
Copper Conductor Size Range:	#12 - #6 AWG
Conductor Size Range (mm):	4 – 10
Flammability Rating:	Flame Retardant
Max. Connector O.D. (In.):	.350
Max. Connector O.D. (mm):	8.9
Max. Recovered I.D. (In.):	.15
Max. Recovered I.D. (mm):	3.8
Min. Cable O.D. (In.):	.170
Min. Cable O.D. (mm):	4.3
Min. Expanded I.D. (In.):	.40
Min. Expanded I.D. (mm):	10.1
Nominal Recovered Wall Thickness (In.):	.090
Nominal Recovered Wall Thickness (mm):	2.3
Shrink Ratio:	3:1
Temperature Range:	-85°F to 230°F (-65°C to 110°C)

Figure D11. Heat shrink tubing product data sheet.

Service Wire Co.

Manufacturing quality. Delivering service.

Single Conductors



XLP USE-2 RHH/RHW-2 600 Volt, Copper

Standards:
UL 44 and UL 854, ICEA S-95-658/NEMA WC-70, C (UL) US
Federal spec. A-A-59544
600 Volt UL/1000 Volt CSA
Available Gasoline and Oil Resistant II and L-824C
ROHS compliant
-40° C rated
Direct Burial/Sunlight resistant

Application:
Types USE-2, RHH/RHW-2 are suitable for use in general purpose wiring applications and may be installed in raceway, conduit, direct burial and aerial installations.

Description:
Single copper conductor, stranded, insulated with moisture and heat resistant, chemically cross-linked polyethylene insulation. Temperature rating 90° C in wet and dry applications. Colors available.

XLP USE-2, RHH/RHW-2

Size AWG or MCM	Strand (no.)	Insulation Thickness (mils)	Approx. Diameter Overall (inch)	Approx. Net Weight per 1000 feet (lbs.)	Ampacity* 90°C Wet/Dry
14	7	45	.169	22	35†
12	7	45	.188	30	40†
10	7	45	.212	45	55†
8	7	60	.272	73	80
6	7	60	.310	107	105
4	7	60	.358	161	140
3	7	60	.382	193	165
2	7	60	.419	244	190
1	19	80	.484	307	220
1/0	19	80	.523	379	260
2/0	19	80	.567	469	300
3/0	19	80	.617	582	350
4/0	19	80	.673	724	405
250	37	95	.773	873	455
300	37	95	.819	1027	505
350	37	95	.871	1200	570
400	37	95	.918	1349	615
500	37	95	1.011	1683	700
600	61	110	1.116	2014	780
750	61	110	1.226	2508	885

* Per NEC-Table 310-17.
The overcurrent protection for items marked with an obelisk (†) shall not exceed 15 amps for 14 AWG, 20 amps for 12 AWG, and 30 amps for 10 AWG per NEC 310-17 footnote.
NOTE: The data shown is approximate and subject to standard industry tolerances. 2007

Figure D12. Electrical conductor wire product data sheet.

Appendix E: EOP System Operation and Maintenance Manual

Drytronic, Inc.

Fort Drum EOP Installation Project
Task Order: 6014-DRYT-001
Prime Contract: F09650-03-D001 Prime Order: 5014

OPERATION AND MAINTENANCE MANUAL

The EOP System should provide many years of trouble-free service with very little maintenance. An EOP System consists of five main components: *anodes*, *cathodes*, *lead wires*, *connections*, and *Control Panels*. Each component has been carefully selected for durability and reliability. Anodes, cathodes, and lead wires are expected to have a service life of over 100 years. We are very careful to protect all connections to prevent any potential corrosion damage. The Control Panel presents the greatest risk of failure and is therefore the focus of this Manual.

Service and Information

For all service questions or any information regarding the EOP System, please contact the following individual:

Paul Femmer
President
OsmoTech, LLC
17295 Chesterfield Airport Road, Suite 200
Chesterfield, Missouri 63005
Toll Free: 1-800-OSMO-030
Office: 1-636-733-7570
Cell: 1-636-346-7379
Email: pfemmer@osmotech.net

General Information:

The DSP Automation "*Control Panel*" is a self-contained unit which consists of (a) one *Master Control Unit* and (b) from 2 to 6 *Slave Control Modules*. Each Slave Control Module is protected on the A/C input by means of a circuit breaker. The D/C output is also protected internally.

Master Control Unit:

The Master Control Unit has LED light at the upper right hand corner of the board.

The LED light is normally "green" in color, and will intermittently flash "red" when communicating with the Slave Control Modules.

Slave Control Modules:

The Slave Control Modules have a led light at the upper right hand corner of the board:

"Green" light indicates module in operation.

"Orange" light indicates a fault on the D/C has been encountered and the unit is in the process of correcting the fault.

"Red" light indicates D/C fault and unit needs to be reset.

To reset Slave Control Module, turn off circuit breaker at the A/C input to module, and then turn the module "on". If red light stays on, module is faulty and needs to be returned to OsmoTech for repairs. Contact OsmoTech for a prepaid FedEx billing number, and express ship the module to the OsmoTech office above.

Master-Slave Connection:

Each module is equipped with a mini 3P connector for making a local connection with a laptop computer.

Software:

One copy of the software is being supplied for use onsite. The software is windows-compatible and self explanatory.

Please note that no adjustments are to be made using the software without written approval from Drytronic Inc. and the Army Corp of Engineers.

The sole purpose of the issuance of the software is to monitor the real time operating parameters of the equipment.

As the software is further developed, an updated version will be provided to the owner at no extra cost.

Monitoring:

The units should be monitored monthly to insure that there is A/C input and D/C output.

When other trades are to work in the basement of the P10000 Building, they should be informed that the EOP System is installed. Careful attention must be taken when cutting, drilling and coring into the floor. Please locate and mark for easy identification the anode and cathode wires which may be in close proximity of the construction area. If a wire or anode were to be accidentally cut, please contact OsmoTech immediately using the above contact information.

Cut Sheets:

The catalog cut sheets (Appendix D) describe all the materials used in this installation.

REPORT DOCUMENTATION PAGE

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June 2007

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5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER
Corrosion Prevention and Control

6. AUTHOR(S)
Orange S. Marshall

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14. ABSTRACT
Hays Hall, headquarters for the U.S. Army 10th Mountain Division, has had a severe moisture intrusion problem since it was constructed, with large volumes of water seeping through concrete walls and floors of the basement. The year after the building underwent acceptance commissioning, the basement flooded to a depth of 4 ft, and $200,000 worth of electronics and communications equipment was destroyed by water damage and severe corrosion. Sump pumps were installed to mitigate the water intrusion problem, but during the rainy season each spring the pumps have been unable to completely eliminate water inflow. The basement still floods to a depth of several inches during heavy rains. One of the pumps had to be replaced after less than half its expected service life.

To address these continuing problems, an electro-osmotic pulse (EOP) system was installed in the basement of Hays Hall during the first and second quarters of Fiscal Year 2006. The system was activated in June 2006, and the U.S. Army Engineer Research and Development Center is monitoring long-term effectiveness of the system to prevent flooding of the basement. To date the EOP system is successfully preventing water intrusion and is keeping the interior walls and floors dry.

15. SUBJECT TERMS
Fort Drum, NY, electro-osmotic pulse (EOP), concrete walls, anodes, cathodes, moisture control, waterproofing

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			**19b. TELEPHONE NUMBER** *(include area code)*
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